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Precambrian Geology of the Cloyne–Plevna–Ompah Area, Northern Mazinaw Domain, Grenville Province

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Precambrian Geology of the Cloyne–Plevna–Ompah Area, Northern Mazinaw Domain, Grenville Province

by

R.M. Easton

2006

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MAP

Preliminary Map P.3443. Precambrian Geology, Cloyne–Plevna–Ompah Area .... back pocket

Abstract

The Cloyne–Plevna–Ompah area, bounded by latitudes 44°50′00″N and 45°07′30″N and longitudes 76°45′00″W and 77°15′00″W, is located approximately 230 km northeast of Toronto. The map area lies within the Central Metasedimentary Belt of the Mesoproterozoic Grenville Province. This report summarizes the results of 3 map areas studied in detail by the Ontario Geological Survey during the period 1991 to 1993, and integrates this new information with data from 3 previously mapped areas.

Most of the synoptic area lies within the Mazinaw domain, which consists largely of metavolcanic and metasedimentary rocks and granitoid plutons that typify the dominant rock associations of the Central Metasedimentary Belt. Mazinaw domain, however, also exhibits some geological features that distinguish it from the rest of the Central Metasedimentary Belt. These include

1. the Flinton Group, a fluvial to shallow-marine metasedimentary assemblage unconformably overlying the older supracrustal and plutonic rocks.
2. a northeast-trending structural pattern with predominantly steep folds and faults.
3. metamorphism that locally reached upper amphibolite facies, in contrast to the generally low- to intermediate-grade nature of adjacent Central Metasedimentary Belt terranes and domains.

A small area of Grimsthorpe domain rocks are present in the extreme southwest corner of the synoptic area. The northwest part of the map area contains rocks characteristic of the Black Donald domain. This study focussed mainly on rocks of Mazinaw domain.

Within the synoptic area, Mazinaw domain may be more divided into 2 tectonic elements. An "arc"-dominated succession in the south, and a "rifted-arc" succession in the north, with the Fernleigh belt (Flinton Group) marking the approximate boundary between them. The "arc" succession constitutes 1275 million-year-old calc-alkalic metavolcanic and metasedimentary rocks that were intruded by the Northbrook–Cross Lake batholith at circa 1250 Ma. The "rifted-arc" succession comprises tholeiitic metavolcanic and related metasedimentary rocks that are intruded by Methuen Suite granites and Lavant Suite gabbros, all emplaced at circa 1245 Ma.

On a regional scale, the rifted-arc succession is south facing, consisting of a gabbro-amphibolite-tonalite basement cut by granite, that is overlain by Mazinaw Lake Formation metavolcanic rocks that, in turn, interfinger with or are overlain by siliciclastic and carbonate metasedimentary rocks. Volcanic centres in the rifted-arc succession are present north of Cloyne, near Plevna, and near Flower Station, in the Darling area located to the northeast of the synoptic area. Metasedimentary rocks in the rifted arc differ from those present in the arc succession in that the rifted arc contains possible stromatolite-bearing dolomite marbles (overall, dolomitic marble is more abundant in the rifted-arc than in the arc succession), and more turbiditic siliciclastic rocks. The rifted arc may be built on a basement complex consisting of amphibolite, Killer Creek Suite gabbroic rocks and Elzevir Suite tonalitic and granodioritic rocks. This basement complex is intruded by sheet-like granite intrusions of the Methuen Suite (circa 1245 Ma).

In contrast, the arc succession is north facing on a regional scale, consisting of Tudor Formation low-potassium tholeiitic metavolcanic rocks overlain by calc-alkalic Kashwakamak Formation metavolcanic rocks. The latter interfinger with or are overlain by siliciclastic and carbonate metasedimentary rocks. Emplacement of the Northbrook–Cross Lake batholith appears to have been localized at the contact between the Tudor and Kashwakamak formations. Volcanic centres related to the arc are located in the Harlowe–Nervine Lake area and near La France Lake.

Distribution and composition of Flinton Group strata varies depending on whether it lies on rocks of the rifted arc or the arc. In the rifted arc, Flinton Group rocks are patchy in their distribution, and consists mainly of metapelite and locally derived conglomerate. Where present, Flinton Group strata occur around intrusions or volcanic centres that conceivably would have been topographic highs during Flinton Group sedimentation. If the current distribution of Flinton Group rocks tells us anything about transport direction, then these rocks are generally found north and east of the inferred highs. The very regular distribution of patches of Flinton rocks in this region, suggest that it may once have been more widespread than current preservation might otherwise suggest (i.e., a thin veneer over much of the belt).

In contrast, in the arc, the Flinton Group is dominated by meta-arenite and metaconglomerate (Bishop Corners and Ompah formations). The Bishop Corners Formation is derived from the Harlowe volcanic centre, whereas the Ompah Formation is derived from the La France–Sunday Lake volcanic centre. If current distribution of Flinton Group strata in the arc tells us anything about transport direction, then these rocks are generally found southwest of the inferred sources, suggesting a similar transport direction. This is the opposite of transport directions that are inferred from the rifted arc.

Plutonic rocks of the Killer Creek (>1270 Ma), Elzevir (circa 1270 and 1250 Ma), Lavant (circa 1250 Ma) and Methuen (circa 1250 Ma) suites occur in Mazinaw domain. Plutonic rocks of the Killer Creek Suite are not found in the Black Donald domain in the synoptic area, which is dominated by plutonic rocks of the Elzevir and Lavant suites.

The area has been subjected to a complex metamorphic and structural history. These include formation of the original arc sequence, extension of that arc to form the rifted-arc sequence at circa 1245 Ma, and subsequent uplift and exposure on surface prior to deposition of the Flinton Group after circa 1160 Ma. Following Flinton Group deposition, the area was subjected to high-grade regional metamorphism and folding in the period between 1080 and 1040 Ma, which affected all units within Mazinaw domain. Metamorphic cooling was slow, with closure through the closure temperature of hornblende occurring at roughly 940 Ma. The presence of the Flinton Group, and a period of relatively late metamorphism followed by slow cooling makes Mazinaw domain unique from other parts of the Elzevir terrane of the Central Metasedimentary Belt.

A variety of mineral occurrences are found within Mazinaw domain. Gold mineralization is found in the southwest corner of the synoptic area, in association with major regional shear zones and the greenschist-amphibolite facies metamorphic transition. Porphyry copper-gold mineralization may also be present in association with older arc-related tonalite plutons and adjacent country rocks. Rhyolites within the Mazinaw Lake Formation, dated at 1250 million years old, have FIII-type chemistry and may host volcanogenic massive sulphide mineralization. A modern alluvium survey in the southwest corner of the synoptic area reported gahnite grains from a sample located adjacent to a Mazinaw Lake Formation volcanic centre, also indicating a high potential for volcanogenic massive sulphide mineralization. Metasomatic iron skarn deposits occur in several places in the synoptic area. Uranium-thorium mineralization is associated with granite pegmatites in the northeast corner of the synoptic area, which has been subjected to the highest metamorphic grades (upper amphibolite facies).

A variety of industrial minerals are present in the synoptic area, including garnet, sillimanite, muscovite, feldspar, talc, tremolite and relatively pure calcitic and dolomitic marbles.

Precambrian Geology of the Cloyne–Plevna–Ompah Area, Northern Mazinaw Domain, Grenville Province

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Open File Report 5454
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Introduction

The Cloyne–Plevna–Ompah area (Figures 1 and 2), bounded by latitudes 44°50′00″N and 45°07′30″N and longitudes 76°45′00″W and 77°15′00″W, is located approximately 230 km northeast of Toronto. The map area covers about 1680 km^2, and represents a compilation of 3 map areas studied in detail by the author during the period 1991 to 1993, and 3 previously mapped areas, as outlined in Figure 1. The Cloyne–Plevna–Ompah map area includes parts of 4 National Topographic System (NTS) 1:50 000 scale map sheets[1]: 31 C/14, 31 C/15, 31 F/2 and 31 F/3. The Cloyne–Plevna–Ompah area lies within parts of Frontenac, and Lennox and Addington counties, and includes parts of Abinger, Anglesea, Barrie, Clarendon, Denbigh, Effingham, Kaladar, Kennebec, Lavant, Miller, North Canonto, Olden, Palmerston, and South Canonto townships. The village of Ardoch is located roughly in the centre of the study area.

The following conventions are used in this report when referring to the various parts of the study area that are shown in Figure 1. "Synoptic area" refers to the entire study area shown on Figure 1 and 2, represented by Map P.3443 (back pocket). It includes the following detailed study areas, numbered from 1 to 6 in Figure 1:

1. Wensley area (this study; Easton and Ford 1991)
2. Palmerston Lake area (Easton 1992c; Ford 1992; Easton, Ford and Cooke 1995)
3. Ardoch area (Pauk 1987)
4. Northern part of the Kennebec area (Harding 1944)
5. Northern part of the Marble Lake area (Moore and Morton 1986)
6. Mazinaw Lake area (Easton and Ford 1991; Easton, Ford and Stewart 1995)

Only areas 2, 6 and the southern part of area 1 were the subject of detailed mapping by the author during the 1991 to 1993 field seasons.

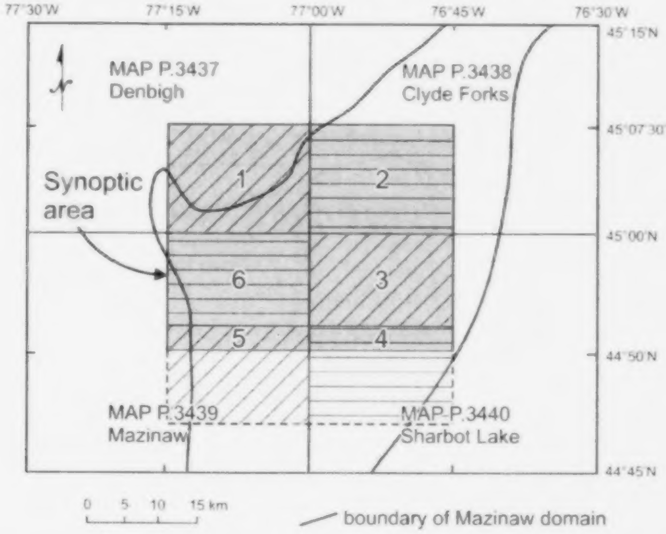

Figure 1. Location of synoptic area that is covered by Map P.3443 and this report (heavy shading) in relationship to other mapping conducting in the area (lined patterns). 1 = Wensley area; 2 = Palmerston Lake area; 3 = Ardoch area; 4 = Kennebec area; 5 = Marble Lake area; 6 = Mazinaw Lake area.

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[1] NTS map sheet area numbers and names: 31 C/14 (at the time of mapping, and retained within this report, Mazinaw Lake; however, the name of this NTS area has since been changed to Bon Echo), 31 C/15 (Sharbot Lake), 31 F/2 (Clyde Forks) and 31 F/3 (Denbigh)

ACCESS

Access is provided by several main roads that join with Highway 41, which extends northerly along the western boundary of the synoptic area. These include the following:

1. Buckshot Lake road, which extends easterly, linking Highway 41 and Plevna along the northern boundary of the synoptic area
2. Frontenac County road 506, formerly provincial highway 506, which extends easterly to northeasterly, linking Highway 41 and Plevna in the central part of the synoptic area
3. Frontenac County road 509, formerly provincial highway 509, which extends northeasterly from Plevna to Ompah in the northeast part of the synoptic area
4. The Clarendon, Coxvale and Ardoch roads, which extend southeasterly, link Ardoch with Frontenac County road 509 at Clarendon Station

Several small hamlets are present in the southern and central parts of the synoptic area, and include Ardoch, Cloyne, Ompah and Plevna. Numerous secondary and logging roads, of varied vintage and quality, branch off of the main access roads and provide reasonable access to most of the synoptic area. In addition, a northeast-trending, major hydro transmission corridor (3 lines) transects the synoptic area from Bishop Corners through Ompah, providing access to most of the central part of the map area. Several large lakes in the area provide water access; these include Brule, Canonto, Crotch (Cross), Gull,

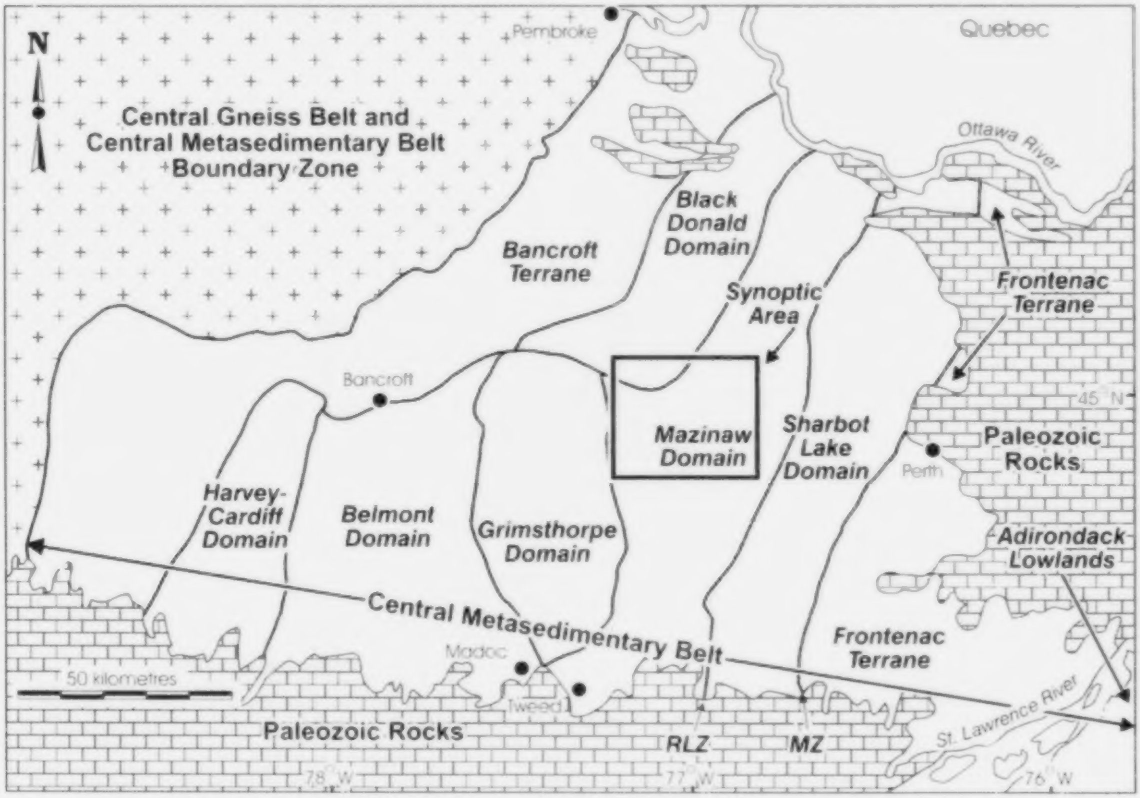
N
Pembroke
Quebec
Central Gneiss Belt and Central Metasedimentary Belt Boundary Zone
Ottawa River
Black Donald Domain
Bancroft Terrane
Synoptic Area
Frontenac Terrane
Bancroft
45° N
Mazinaw Domain
Sharbot Lake Domain
Perth
Paleozoic Rocks
Harvey-Cardiff Domain
Belmont Domain
Grimsthorpe Domain
Adirondack Lowlands
Central Metasedimentary Belt
Frontenac Terrane
Madoc
Tweed
50 kilometres
St. Lawrence River
Paleozoic Rocks
RLZ
MZ
78° W
77° W
76° W

Figure 2. Location of synoptic area with respect to domains and terranes present within the Central Metasedimentary Belt, Grenville Province, Ontario. Domain and terrane subdivision *after* Easton (1992b).

Kashwakamak, Mazinaw, Mississagagon, and Palmerston lakes.[2] Cottages are located along many of these larger lakes, and cottage roads provide additional access throughout the synoptic area. In general, access is more abundant in the southern part of the synoptic area than in the north.

PHYSIOGRAPHY

Relief in the synoptic area is generally less than 150 m, ranging from roughly 260 m above sea level (asl) in the southern part of the area to 400 m asl in the north. Average elevation is between 290 and 335 m asl. Outcrop is most abundant in areas underlain by granitic rocks (30 to 50% exposure) and is least abundant in areas underlain by marbles (5 to 10% exposure). Areas underlain by marble, particularly in the southern part of the synoptic area, were cleared at the turn of the century for farming, which continues into the present. Except for parts of Frontenac County road 506, which follows an outcrop ridge that parallels the core of the Fernleigh belt, most major transportation corridors follow areas of thick glaciolacustrine cover.

PREVIOUS GEOLOGICAL INVESTIGATIONS

W.G. Miller and C.W. Knight (1914) mapped in detail 2 geographically small areas, one east of Cloyne and another near Ompah; however, systematic mapping at 1:63 360 scale of Anglesea and Barrie townships and Kaladar and Kennebec townships, which transect the central part of the synoptic area, did not take place until the early 1940s (Meen (1944) and Harding (1944), respectively). This earlier mapping served as the basis for the 1:126 720 scale compilation map of Hewitt (1964), which covers the southern two-thirds of the synoptic area.

Moore and Morton (1986) mapped the Marble Lake area (area 5, *see* Figure 1) and Pauk (1987) mapped the Ardoch area (area 3, *see* Figure 1), both at 1:31 680 scale. Easton and Ford (1990, 1994a, 1994b) mapped the Grimsthorpe area, adjacent to the western boundary of the synoptic area at 1:20 000 scale. Easton (1994) also summarized the geology of Bon Echo Provincial Park, which straddles the west-central boundary of the synoptic area. Wolff (1982a, 1982b) mapped the Kaladar and Long Lake areas, which adjoin the southern boundary of the synoptic area at 1:31 680 scale. Wolff (1985) and Pauk (1989a, 1989b) mapped the Sharbot Lake, Dalhousie Lake and Lavant areas, all of which adjoin the eastern boundary of the synoptic area, all at 1:31 680 scale. Karboski (1980) mapped the Norcan Lake area, which adjoins the northeastern boundary of the synoptic area at 1:15 840 scale as part of a MSc thesis at Carleton University. Geological compilation maps of the 4 NTS map sheets that encompass the synoptic area have been published at 1:50 000 scale (Lumbers and Vertolli 2001; Easton 2001a, 2001b, 2001c). Lake sediment surveys also cover the synoptic area (Ontario Geological Survey–Geological Survey of Canada 1977a, 1977b). Industrial mineral inventories cover the northern half of the synoptic area (Storey and Vos 1981a, 1981b).

Moore and Thompson (1972, 1980) and Thompson (1972, 1973) studied the Flinton Group metasedimentary rocks in the synoptic area in detail. Geochemical studies on metavolcanic rocks south of the map area in the vicinity of Cloyne and Harlowe have been conducted by Sethuraman (1970), Baragar (1972), Sethuraman and Moore (1973), Ayer (1979), Harnois (1988a), Harnois and Moore (1991) and Easton and Ayer (1994). Mannard (1982) studied the chemistry of metavolcanic rocks in the Coxvale area. Easton (1995) briefly describes the geochemistry of the Flinton Group.

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[2] Crotch Lake was formerly named Cross Lake, hence, "Cross Lake batholith". In the time since the field work was completed, Mazinaw Lake has been divided into Upper Mazinaw Lake and Lower Mazinaw Lake, however, for simplicity within this report, the author will use "Mazinaw Lake" or "Mazinaw" area.

Smith, Vogel and Spence (1969) studied the contact relationships of the Norway Lake Granite and surrounding rocks in detail. A doctoral thesis by Spence (1968) on the metavolcanic rocks adjacent to the Norway Lake Granite was part of this study. This topic was revisited when Cooke (1992) studied the Flinton Group metasediments adjacent to the northwestern terminous of the Norway Lake Granite (Mazinaw area) as a BSc thesis at Queen's University under the supervision of H. Helmstaedt.

Connelly (1985, 1986) and Connelly, van Breemen and Hanmer (1987) studied the emplacement history of the Elzevir Tonalite, including detailed studies along the eastern margin of the pluton in the Bishop Corners and Harlowe areas near the western boundary of the synoptic area. Rivers (1976) studied the metamorphism and structure in the Fernleigh to Ompah area. Hutcheon (1972), Hutcheon and Moore (1973), Hounslow (1965), Hounslow and Moore (1967), Thompson (1972, 1973), Finn (1978), Yatabe (1982) and Ford (2002) have all conducted detailed metamorphic studies in the western half of the synoptic area. Chapman (1968) and Chapman-Kamilli (1974) studied the metamorphic history of the Northbrook and Cross Lake tonalites in detail.

Schwerdtner, Downey and Alexander (2004) studied high-strain zones in Mazinaw domain and concluded that these zones qualify as stretching thrusts that were most likely active in a midcrustal regime of northwest-directed thrusting, most likely during the Ottawan orogeny. Schwerdtner, Serafini and Burke (2004) and Schwerdtner, Serafini and Yakovenko (2005) describe preliminary results from the northern boundary of Mazinaw domain.

A preliminary Rb/Sr geochronologic study covering the synoptic area was conducted by Bell and Blenkinsop (1980); however, this work has been superseded by a detailed U/Pb zircon and titanite study of the northern Mazinaw domain, including the synoptic area, by Corfu and Easton (1994, 1995). The geochronological study of Corfu and Easton (1994, 1995) resulted in considerable changes to the regional stratigraphy of the synoptic area from previous work (including Moore and Morton 1986; Pauk 1987; Ayer 1979; Rivers 1976; Easton and Ford 1991), as detailed herein. Kinsman (1990), Sager-Kinsman and Parrish (1993), and Peters (1993) examined detrital zircons from the Flinton Group and Sager-Kinsman and Parrish (1993) report a maximum age of deposition for the Flinton Group near Harlowe.

Field trip stops, mainly in the Marble Lake and Mazinaw areas are described in guidebooks by Moore (1967), Moore and Wynne-Edwards (1967), Carmichael, Moore and Skippen (1978), Davidson, Carmichael and Pattison (1990), Easton and Davidson (1994a), and Davidson and Easton (1994, 1998).

PRESENT GEOLOGICAL SURVEY

This report summarizes the results of 3 separate Ontario Geological Survey projects, as follows:

1. project unit 91-008: 1:20 000 scale mapping of the Mazinaw and Bon Echo Park areas in 1991.
2. project unit 92-005: 1:20 000 scale mapping of the Palmerston Lake area in 1992.
3. project unit 93-025: producing a series of 1:50 000 scale compilation maps centred on longitude 77°00′W.

This report is accompanied by Map P.3443 (back pocket), which represents a 1:50 000 scale geological compilation map of the synoptic area and which also includes previously unpublished mapping from the Wensley area conducted during the 1991 and 1992 field seasons. Table 1 provides a complete listing of previously published products related to these 3 projects.

Table 1. Listing of publications, in addition to this study, related to project units 91-008, 92-005 and 93-025.

Project Number	Publication	Remarks
91-008	Easton, R.M. and Ford, F.D. 1991. Geology of the Mazinaw area; Ontario Geological Survey, Miscellaneous Paper 157, p.95-108.	Summary of Field Work article
	Easton, R.M. 1992. Potential porphyry copper mineralization within the Mazinaw Terrane, Grenville Province; Ontario Geological Survey, Open File Report 5828, 23p.	Mineral potential assessment
	Cooke, M.A. 1992. Petrography and origin of metasedimentary clastic rocks overlying the Norway Lake Granite near Plevna, Ontario; unpublished BSc thesis, Queen's University, Kingston, Ontario, 42p.	BSc thesis study on rocks adjacent the Norway Lake granite in the Mazinaw area
	Easton, R.M. 1994. Geology of Bon Echo Provincial Park; Ontario Geological Survey, Open File Report 5899, 54p.	Accompanied by Map P.3270
	Easton, R.M., Ford, F.D. and Stewart, R. 1995. Geology of the Mazinaw area (31 C/14NE); Ontario Geological Survey, Preliminary Map P.3336.	1:20 000 uncoloured map of Mazinaw area
92-005	Easton, R.M. 1992. Geology of the Palmerston Lake area; Ontario Geological Survey, Miscellaneous Paper 160, p.29-40.	Summary of Field Work article
	Easton, R.M. 1992. Geology of the Palmerston Lake area, Mazinaw Terrane, Grenville Province; Ontario Geological Survey, Geoscience Research Seminar, December 7-9, 1992, Abstracts, p.31.	Poster presentation of preliminary mapping results
	Ford, F.D. 1992. Geology of the Fernleigh and Ompah "synclines", Palmerston Lake area; Ontario Geological Survey, Miscellaneous Paper 160, p.41-46.	Summary of Field Work article
	Easton, R.M. 1993. Regional block faulting of eastern Ontario in the Paleozoic: evidence from detailed mapping within the Grenville Province; Geological Association of Canada–Mineralogical Association of Canada, Program with Abstracts, v.18, p.A-25.	Poster presenting results based on mapping in the Palmerston Lake area
	Easton, R.M. and Ayer, J.A. 1994. VMS potential of the Mazinaw Terrane, Grenville Province; Ontario Geological Survey, Miscellaneous Paper 163, p.27-30.	Summary of Field Work article
	Easton, R.M., Ford, F.D. and Cooke, M.A. 1995. Geology of the Palmerston Lake area (31 F/2SW); Ontario Geological Survey, Preliminary Map P.3335.	1:20 000 uncoloured map, includes unpublished data of L. Pauk for the Sunday Lake area
91-008, 92-005	Easton, R.M. and Ford, F.D. 1992. Enigmatic basement–cover relationships within the Central Metasedimentary Belt, Ontario - yet another look at the Flinton Group; 1992 FOG Workshop, Abstracts, p.12.	Poster presentation of results related to Flinton Group stratigraphy
	Corfu, F. and Easton, R.M. 1994. U/Pb ages for volcanism, plutonism and metamorphism in the Mazinaw Terrane, Grenville Province, Ontario; Geological Association of Canada–Mineralogical Association of Canada, Program with Abstracts, v.19, p.A22.	Preliminary geochronology results
	Davidson, A. and Easton, R.M. 1994. Terranes and their boundaries in the Central Metasedimentary Belt, Grenville Province, Ontario; Friends of The Grenville, 1994 Guidebook, Ottawa, Ontario, 26p.	Field trip guidebook includes stops in synoptic area
	Easton, R.M. and Davidson, A. 1994. Terrane boundaries and lithotectonic assemblages within the Grenville Province, Eastern Ontario; Guidebook A1, Waterloo '94, Geological Association of Canada, 89p.	Field trip guidebook includes stops in synoptic area
	Corfu, F. and Easton, R.M. 1995. U-Pb geochronology of the Mazinaw Terrane: an imbricate segment of the Central Metasedimentary Belt, Grenville Province, Ontario; Canadian Journal of Earth Sciences, v.32, p.959-967.	Final geochronology results
	Easton, R.M. 1995. Regional geochemical variation in Grenvillian carbonate rocks: implications for mineral exploration; Ontario Geological Survey, Miscellaneous Paper 164, p.6-18.	Summary of Field Work article on geochemistry of carbonate rocks in Mazinaw and Palmerston areas
	Easton, R.M., Ford, F.D., van Haaften, S. and Smedley, J.A. 1991, 1994, 2001. Geology of Bon Echo Provincial Park; Ontario Geological Survey, Open File Map 166 (1991), Preliminary Map P.3270 (1994), and Preliminary Map P.3270—Revised (2001).	All 3 versions released at 1:20 000 scale. The 2001 release was in colour and incorporated legend changes due to the geochronology study of Corfu and Easton (1995).
	Davidson, A. and Easton, R.M. 1998. From Front to interior: an Ontario transect of the Grenville Province from Sudbury, Ontario to the St. Lawrence; Geological Society of America, Toronto '98, Field Trip Guidebook, 51p.	Field trip guidebook includes stops in synoptic area
93-025	Easton, R.M. 2001. Geology of the Clyde Forks area (31 F/2); Ontario Geological Survey, Preliminary Map P.3438.	Colour compilation map, 1:50 000 scale, northeast corner of synoptic area
	Easton, R.M. 2001. Geology of the Mazinaw Lake area (31 C/14); Ontario Geological Survey, Preliminary Map P.3439.	Colour compilation map, 1:50 000 scale, southwest corner of synoptic area
	Easton, R.M. 2001. Geology of the Sharbot Lake area (31 C/15); Ontario Geological Survey, Preliminary Map P.3440.	Colour compilation map, 1:50 000 scale, southeast corner of synoptic area

For the Mazinaw and Palmerston Lake areas, geological mapping was conducted using vertical aerial photographs at a scale of 1:10 000 supplied by the Air Photo Library, Public Information Centre, Ontario Ministry of Natural Resources. Acetate overlays were used to record data that was collected on traverses run by the pace and compass method. Geology was not tied to surveyed lines. Traverses were not spaced at regular intervals, but were designed to include as many of the major outcrop areas as possible, particularly in areas of complex geology and along contacts between major rock units. Traverse density was greater in areas underlain by supracrustal rocks than in areas underlain by large plutons.

Information from mapping in the Mazinaw and Palmerston Lake areas was plotted on Ontario Base Mapping (OBM) 1:10 000 base maps supplied by the Ontario Ministry of Natural Resources. Recent information with respect to roads, buildings, power lines, rock and shoreline features was added to the base maps. For each detailed area, the approximately 18 OBM base maps were mechanically stripped together, and photomechanically reduced, with the geological information, to produce the 2 1:20 000 scale maps related to this study (Easton, Ford and Stewart 1995; Easton, Ford and Cooke 1995). The synoptic area map—Map P.3443—was plotted at 1:50 000 scale, digital base maps supplied by Natural Resources Canada.

Except where otherwise stated, all chemical analyses that appear in this report were done by the Geoscience Laboratories, Ontario Geological Survey, Sudbury. Reference to specific locations (photographs, samples, etc.) are given in Univeral Transverse Mercator (UTM) co-ordinates, North American Datum 1927 (NAD27), Zone 18, because of the ability to pinpoint locations more precisely than by using latitude and longitude or lots and concessions.

ACKNOWLEDGMENTS

Fred Ford served superbly as senior assistant during both the 1991 and 1992 field seasons. During the 1991 field season, the author was ably assisted by Melanie Cooke and Randy Stewart; the latter conducted independent mapping over much of the northern half of the Mazinaw area. Angeline Lundquist served as a junior assistant for part of that field season. During the 1992 field season, able assistance was provided by Melanie Cooke, Susan Buckley and Jake Jakop. Melanie Cooke conducted independent mapping during part of the 1992 field season, in addition to collecting data for a BSc Honours thesis (Cooke 1992). Brad Leonard assisted briefly during some follow-up field work in the Palmerston Lake area in 1993. Susan Buckley collected thermobarometric data related to this project in 1996. Elena Murphy provided assistance with digital drafting of some of the report figures in 2001. The assistance of various staff members at Bon Echo Provincial Park Headquarters, including superintendent E.M. Buck and park naturalist Denise Wilkins is greatly appreciated. Many land owners in the area kindly granted permission to inspect their properties, and their assistance is greatly appreciated. Discussions with Sharon Carr, Brian Christie, Fernando Corfu, Tony Davidson, Paul Kingston, Peter LeBaron, John Moore and Chris Papertzian on the geology of the area also proved helpful.

TERMINOLOGY

A number of terms used in this report are outlined below.

Precambrian Time Scale

The Precambrian time scale as subdivided by Easton (1999) is used. This is an updated version of the time scale used for *Geology of Ontario* (Ontario Geological Survey 1992). Precambrian time is divided into 2 eons: the Archean (older than 2500 Ma), and the Proterozoic (between 2500 and 543 Ma). The Proterozoic is divided into 3 eras: Paleoproterozoic (2500 to 1600 Ma); Mesoproterozoic (1600 to 900 Ma); and Neoproterozoic (900 to 543 Ma).

Rock Classification

Terminology for all plutonic rocks in the area follows that of Streckeisen (1976). For metamorphic rocks, mineral prefixes are listed in order of relative abundance, starting with least abundant first. Mineral abbreviations follow Kretz (1983.) The following conventions are used regarding descriptive adjectives. A *gneissic granite* is a meta-igneous rock of granitic composition. A *granitic gneiss*, a *granite gneiss*, or a *gneiss of granitic composition* may be either a meta-igneous or a metasedimentary rock. Similarly, a *tonalitic gneiss* or a *tonalite gneiss* is a gneiss of tonalite modal composition, but may be of either meta-igneous or metasedimentary origin. A *gneissic meta-arkose* is a metasedimentary gneiss of overall granitic composition.

The synoptic area includes abundant metasedimentary rocks or volcanic provenance (i.e., volcaniclastic rocks). Terminology for such rocks is problematic, and no widely agreed upon classification scheme exists. The International Union of Geological Sciences (IUGS) classification presented by Schmid (1981) divides mixed pyroclast-epiclastic rocks into 3 types: pyroclastic, tuffites (mixed pyroclastic-epiclastic) and epiclastic (volcanic and/or nonvolcanic). Clastic rocks within the synoptic area probably represent all 3 types. Tuffs are certainly present, as are tuffaceous sandstones (mixture of tuff and epiclastic sands) and volcanic-derived sandstones; however, metamorphism and the difficulty in establishing the degree of reworking present in epiclastic debris derived from a pyroclastic source make it impossible to apply the IUGS classification precisely. Consequently, the following modification of the IUGS terminology is used.

Pyroclastic (volcanic)	**Volcaniclastic (epiclastic rocks of mainly volcanic provenance)**	**Epiclastic (minor volcanic component)**	**Average Clast Size (mm)**
Pyroclastic breccia	Tuffaceous conglomerate tuffaceous breccia	Conglomerate breccia	64
Lapilli tuff	Tuffaceous sandstone	Sandstone	2
Tuff – coarse	Tuffaceous siltstone	Siltstone	1/16
Tuff – fine	tuffaceous mudstone	mudstone/shale	1/256
100%	75%	25%	0% by volume

A migmatite is a heterogeneous rock composed of 2 or more components, one generally quartzofeldspathic in composition (leucosome or neosome) and the other more mafic in composition (paleosome or mesosome). Within the study area, such rocks are commonly layered and, in many instances, are formed by partial melting during high-grade regional metamorphism. Descriptive terminology for these rocks follows Mehnert (1971). Other related terms are *metatextite*, a rock resulting from moderate degrees of partial melting, in which leucosome is subordinate to mesosome; and *diatextite*, a rock resulting from high degrees of partial melting and containing substantial amounts of leucosome.

The term "metamorphic grade" is used in the case where bulk-rock composition or other factors prevent a more detailed assignment of metamorphic conditions. Where metamorphic conditions can be outlined more precisely, the metamorphic facies terminology of Turner (1981) is used.

Foliation, Schistosity, Gneissosity, Cleavage

Foliation is used to describe all types of megascopically recognizable structural surfaces of metamorphic origin (Turner and Weiss 1963). Several distinguishable types of foliation include compositional layering and preferred orientation of mineral grains. Bedding and schistosity are the most common varieties of foliation in the synoptic area. Schistosity is accompanied by a fissility in the rock, and is best developed in micaceous rocks. Gneissosity denotes a layering of metamorphic origin, defined by the alternation of layers, streaks, or lenticles on contrasting mineralogy or texture. The streaks or lenticles may be discontinuous. Cleavage denotes a parting in the rock resulting from the parallel growth of micaceous or elongated minerals in fine- to medium-grained rocks.

Layering Thickness Terms

Layering thickness terms used in this report are listed below. These terms apply to bedded, layered and gneissic rocks.

Very thinly layered	<3 cm
Thinly layered	3 to 10 cm
Medium layered	10 to 30 cm
Thickly layered	30 to 100 cm (1 m)
Very thickly layered	1 to 3 m
Extremely thickly layered	>3 m

Geochemical Methods and Terminology

Except where otherwise stated, all chemical analyses that appear in this report were done at the Geoscience Laboratories, Ontario Geological Survey, Sudbury. All chondrite-normalized rare earth element diagrams shown in this report use the normalizing values of Sun and McDonough (1989). All geochemical data collected during this study is listed in Appendix 1. Regardless of year, sample numbers between 0 and 999 were collected by R.M. Easton (years 1991, 1992, 1993, 1995) and sample numbers 1000 to 1999 were collected by F.D. Ford (years 1991 and 1992). Samples numbers 2000 to 2999 were collected either by R. Stewart in 1991 or M. Cooke in 1992 (e.g., sample 92RME-0321 was collected in 1992 by R.M. Easton and sample 91RME-1086 was collected in 1991 by F.D. Ford). Analytical methods are described in Vander Voet and Riddle (1993).

The term "anomalies" is used with reference to background levels determined empirically by this study. For base metals, values of >50 ppm for Zn, >10 ppm for Pb, and >50 ppm for Cu are anomalous with respect to typical marble, as are Sr values >500 ppm. For non-aluminous marbles (<2.0% Al_2O_3), Ba values >200 ppm are anomalous. In the case of rare earth element plots, reference to a cerium anomaly, for example, refers to departure of cerium from the trend of the other rare earth elements, and may be negative (loss relative to the main pattern) or positive (gain). Samples showing higher than background values are sometimes described herein as enriched (e.g., a marble with 1500 ppm Sr would be considered enriched relative to typical Grenville marbles, which typically contain 75 to 350 ppm Sr).

Geological Setting

INTRODUCTION

The Grenville Province in Ontario contains rocks ranging in age from 2690 to 990 Ma. All rocks older than 1300 Ma are pre-Grenvillian; those younger than 1300 Ma are Grenvillian. A variety of subdivisions are in use for the Grenville Province in Ontario, and fall into 2 broad groups: those that are lithologically based, commonly with a long history of usage, and those that are more tectonic or interpretative in character, generally of more recent vintage. Boundaries between the different types do not always coincide (e.g., the Central Gneiss Belt contains para-autochthonous and allochthonous rocks). Both approaches are valid, and are used based on needs (e.g., lithologic and historic based terminology used more on maps (<1:50 000 scale), tectonic-based terminology used on regional maps and in academic literature). Key divisions are listed in Table 2, and those related to the Central Metasedimentary Belt are shown in Figure 1.

The southwestern end of the exposed Grenville Province consists of 2 main elements: the Central Gneiss Belt and the Central Metasedimentary Belt (nomenclature after Wynne-Edwards 1972). The Central Metasedimentary Belt is dominated by supracrustal rocks, deposited between 1300 and 1200 million years ago, which were subsequently intruded by several plutonic suites (e.g., Lumbers et al. 1990; Easton 1992b). The Central Metasedimentary Belt can be divided into a number of lithotectonic terranes and domains (*see* Figure 2) (e.g., Moore 1982; Easton 1992b; Easton and Davison 1994b) separated from one another by shear zones. However, the distinctiveness, boundary relationships, and utility of some of the more newly defined terranes has been questioned (e.g., Moore 1994; Easton and Davidson 1994b); nonetheless, the terrane classification provides a framework for describing regional variations in the geology of the Central Metasedimentary Belt. For the purposes of clarification, a terrane is a fault-bounded package of strata that has a geologic history distinct from the adjoining geologic units. In contrast, a domain is a volume of rock, bounded by compositional or structural discontinuities, within which there is structural homogeneity.

Table 2. Key divisions of the Grenville Province in Ontario.

Historic/Lithologic	Regional Tectonic	Local Tectonic/Historic
Grenville Front Tectonic Zone (GFTZ)	Para-autochthonous belt (Rivers et al. 1989) or Laurentian margin 1 (Carr et al. 2000)	Segments 1, 2, 3
Central Gneiss Belt (CGB) (Wynne-Edwards 1972; Easton 1992b)	Para-autochthonous and/or allochthonous belt (Rivers et al. 1989), Laurentian margin 2 and 3 (Carr et al. 2000)	Parry Sound, Algonquin, Tomiko, Beaverstone terranes Britt, Fishog, Go Home (lower), Go Home (upper), Huntsville, Kiosk, McCraney, McClintock, Moon River, Nepewassi, Novar, Powassan, Shawanaga, Sequin, Tilden Lake domains
Central Metasedimentary Belt (CMB) (Wynne-Edwards 1972; Easton 1992b)	Composite Arc Belt (CAB) and Frontenac–Adirondack Belt (FAB) (Carr et al. 2000)	Bancroft, Elzevir, Frontenac terranes (Elzevir contains Anstruther, Belmont, Grimsthorpe, Mazinaw, Sharbot Lake domains), Adirondack Lowlands and Highlands
Important Boundaries		
Grenville Font (Wynne-Edwards 1972; Easton 1992b)	North limit of Grenville metamorphism and penetrative deformation (locally migmatite front)	Grenville Front boundary fault (GFBF)
Allochthon Boundary Thrust (ABT) (Rivers et al. 1989)	Separates para-autochthonous and allochthonous rocks (Rivers et al. 1989; Carr et al. 2000)	aka central Britt shear zone, Shawanga shear zone
Laurentian Margin–Composite Arc Belt boundary (Carr et al. 2000)	Composite Arc boundary zone (CABZ) (Carr et al. 2000)	Central Metasedimentary Belt boundary zone (CMBBZ), aka Central Metasedimentary Belt boundary thrust zone (CMBbtz)
Composite Arc Belt–Frontenac Adirondack Belt boundary (Carr et al. 2000)	Frontenac–Adirondack boundary zone (FABZ) (Carr et al. 2000)	aka Maberly shear zone, Sharbot Lake–Frontenac boundary

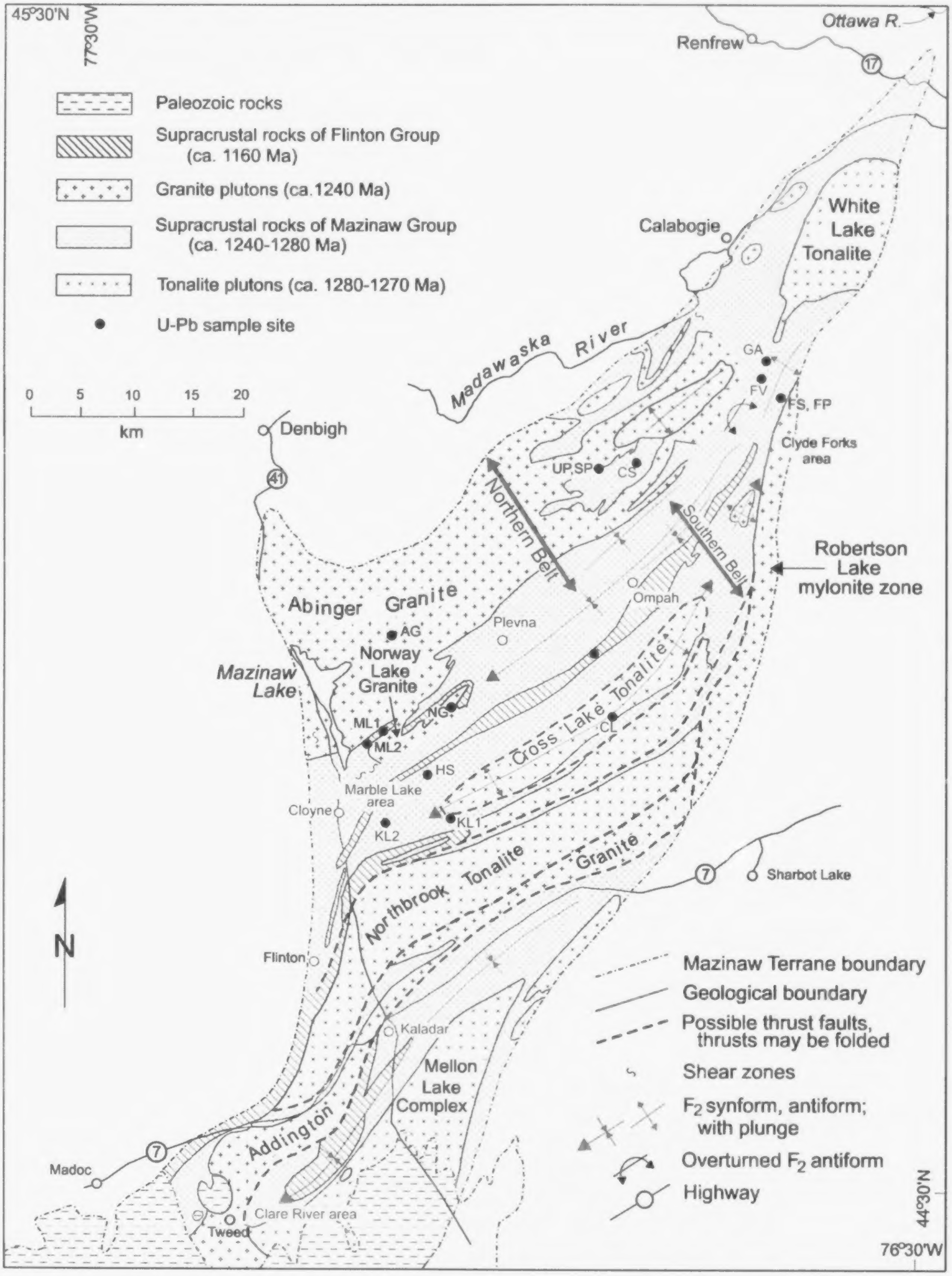
45°30'N
77°30'W
Paleozoic rocks
Supracrustal rocks of Flinton Group (ca. 1160 Ma)
Granite plutons (ca.1240 Ma)
Supracrustal rocks of Mazinaw Group (ca. 1240-1280 Ma)
Tonalite plutons (ca. 1280-1270 Ma)
U-Pb sample site
0 5 10 15 20
km
Ottawa R.
Renfrew
17
Calabogie
White Lake Tonalite
Madawaska River
GA
FV
FS, FP
Clyde Forks area
Denbigh
41
UP,SP
CS
Northern Belt
Southern Belt
Robertson Lake mylonite zone
Abinger Granite
Ompah
Plevna
AG
Norway Lake Granite
Mazinaw Lake
NG
ML1
ML2
Cross Lake Tonalite
CL
HS
Marble Lake area
Cloyne
KL1
KL2
Northbrook Tonalite
Granite
7
Sharbot Lake
N
Flinton
Kaladar
Mellon Lake Complex
Addington
Madoc
7
Clare River area
Tweed
44°30'N
76°30'W
Mazinaw Terrane boundary
Geological boundary
Possible thrust faults, thrusts may be folded
Shear zones
F2 synform, antiform; with plunge
Overturned F2 antiform
Highway

Figure 3. Simplified geological map of Mazinaw domain (*from* Easton 1992b).

Most of the synoptic area lies within the Mazinaw domain. First defined by Easton and Ford (1991), it consists largely of metavolcanic and metasedimentary rocks and granitoid plutons (Figure 3) that typify the dominant rock associations of the Central Metasedimentary Belt. However, Mazinaw domain also exhibits some geological features that distinguish it from the rest of the Central Metasedimentary Belt. These include

1. the Flinton Group, a fluvial to shallow-marine metasedimentary assemblage unconformably overlying the older supracrustal and plutonic rocks
2. a northeast-trending structural pattern with predominantly steep folds and faults
3. metamorphism that locally reached upper amphibolite facies, in contrast to the generally low- to intermediate-grade nature of adjacent Central Metasedimentary Belt terranes and domains

REGIONAL GEOLOGIC SETTING

Before describing the geology of the Mazinaw domain in general, and the synoptic area in particular, brief descriptions of the adjoining geologic terranes and the nature of their contacts with the Mazinaw domain are provided, as these relationships are important in understanding the geologic setting and history of Mazinaw domain.

Grimsthorpe Domain

The Grimsthorpe domain of the Elzevir terrane (Easton 1992b; Easton and Ford 1994a, 1994b) lies to the west of the synoptic area; locally, the western boundary of the synoptic area parallels, or straddles, the boundary between the Grimsthorpe and Mazinaw domains (*see* Figure 2). The Grimsthorpe domain consists of, from oldest to youngest,

1. a sequence of tholeiitic metabasalts intruded by metagabbro and metaperidotite (Canniff Complex)
2. metaconglomerate, metawacke and metapelite (Grimsthorpe Group), with minor intercalated tholeiitic metabasalt flows (Grimsthorpe Group), derived from a dominantly mafic volcanic source region and the Canniff complex. In addition, a suite of tholeiitic gabbro intrusions cut this volcaniclastic sedimentary sequence.
3. metagabbro, with hornblendite pods and anorthositic metagabbros of the Killer Creek Suite (Easton and Ford 1990, 1994a), referred to as Killer Creek-type gabbros, which are greater than 1270 Ma in age
4. metatonalite and minor metagranodiorite of the Elzevir Suite, emplaced at circa 1270 Ma (Easton 1992b; Lumbers et al. 1990), including the Canniff, Elzevir and Weslemkoon tonalites, which locally form intrusion breccias of tonalite and Killer Creek-type gabbro
5. syenitic plutons of the Kensington–Skootamatta Suite, emplaced at circa 1090 to 1065 Ma (Corriveau et al. 1990; Easton 1992b)

Rocks of the Grimsthorpe domain are preserved at greenschist facies in the southern and central parts of the domain, reaching amphibolite facies in the north. Only one major regional metamorphic event appears to have affected the Grimsthorpe domain. Deformation in the domain is localized in shear zones, and most rocks preserve relict primary textures, including igneous layering in the gabbroic rocks and fine bedding features in the metasediments (Easton and Ford 1990, 1994a; Easton and Davidson 1994a).

Mazinaw–Grimsthorpe Domain Boundary

The Mazinaw–Grimsthorpe domain boundary is a narrow shear zone (0.3 to 1 km wide), marked by the development of ductily strained gneissic rocks, and is informally termed the Mooroton shear zone. The zone is well defined south of Flinton (southwest of the synoptic area), where thin slivers of ultramafic rocks and Flinton Group sediments are in tectonic contact with deformed tonalitic and granodioritic rocks of the Elzevir and Northbrook tonalites. Along the western margin of the synoptic area, the trace of the boundary shear zone is more difficult to ascertain in part because i) north-northwest-trending faults run subparallel to the boundary, ii) tholeiitic metabasalts lie on both sides of the boundary and, iii) near Cloyne, little metamorphic contrast is present across the boundary.

Farther north, in the Bon Echo Provincial Park area, the boundary becomes even more difficult to map, mainly because of the abundance of northwest-trending faults in the area (Easton 1994). From a more regional perspective, the boundary is recognized by the following criteria:

1. a change in structural orientation from northerly and northeasterly trends in the Grimsthorpe domain to easterly trends in the Mazinaw domain
2. the presence of granitic dikes and granitic plutons within the Mazinaw domain, which are absent from the Grimsthorpe domain
3. the development of biotite in mafic metavolcanic and metaplutonic rocks in the Mazinaw domain
4. increased deformation and, locally, higher metamorphic grade (or evidence for 2 regional metamorphic events) within Mazinaw domain rocks
5. although metagabbroic and metatonalitic rocks are found in both terranes, calcitic and dolomitic marbles, siliceous clastic metasedimentary rocks, diverse metavolcanic sequences and Flinton Group metasedimentary rocks are absent from the Grimsthorpe domain

Although the case for a regionally significant boundary across the Mooroton shear zone is easily made from regional stratigraphic, structural and metamorphic contrasts, as outlined above, pinpointing the bounding shear zone is more difficult. This is especially true in the western part of the Marble Lake area, where the shear zone is hosted in mafic metavolcanic rocks. Easton and Ford (1990) originally suggested the boundary lay along the Skootamatta River near the Elzevir tonalite–metabasalt contact; however, subsequent mapping (Easton and Ford 1994a), suggests that the boundary may lie several kilometres farther east, approximately halfway between the Elzevir tonalite and Highway 41, roughly coincident with a narrow zone of sulphide mineralization (O'Donnell and related occurrences, Moore and Morton 1986). In the Marble Lake area, the Mooroton shear zone dips steeply to the east. Farther north, in Bon Echo Provincial Park, the Mazinaw–Grimsthorpe domain boundary seems to follow the contact between the Abinger Granite (Mazinaw domain) and metavolcanic and metagabbroic rocks of the Grimsthorpe domain, and the contact, although still east dipping, is considerably shallower. Thus, it is possible that in the Bon Echo Provincial Park area, Mazinaw domain was thrust on top of Grimsthorpe domain rocks (Easton 1994).

Despite these complications, detailed studies along the Mooroton shear zone (Cureton et al. 1994; Ford and Skippen 1994; Connelly 1985, 1986) suggest slightly higher metamorphic temperatures (500 to 550°C in Grimsthorpe versus 550 to 580°C in Mazinaw), significantly higher pressures (3 to 4 kilobars in Grimsthorpe versus 6 to 8 kilobars in Mazinaw), and a contrast in $^{40}Ar/^{39}Ar$ cooling ages (1030 Ma in Grimsthorpe versus 940 Ma in Mazinaw) across the Mooroton shear zone. All these features suggest significant displacement across the Mooroton shear zone, even if locally there is no significant change in rock type across it.

Black Donald Domain

In the northwestern part of the synoptic area, the Abinger Granite is in fault contact with another geological domain, which may be an additional domain of Elzevir terrane, or which may be part of southern Bancroft terrane (*see* Figure 2). Schwerdtner, Serafini and Burke (2004) have suggested that this domain be termed the Black Donald domain, and this terminology is adopted herein.

Black Donald domain consists of a sequence of marble tectonic breccias containing abundant amphibolite blocks and intercalated horizons. In the northernmost Mazinaw area and in the Wensley area, this Black Donald domain consists of a succession of thinly layered, locally migmatitic, paramphibolite and metawacke units, locally with intercalated coarse-grained calcitic marble layers. In the extreme northwestern part of the Palmerston Lake area, rock types within the Black Donald domain consist of layered to bedded, medium-grained, calcite marbles, locally cut by white tonalite and pink granite dikes; thin- to medium-layered amphibolites derived from metavolcanic rocks, volcanic-derived metasedimentary rocks, and mylonitized gabbros; and monzogranite to syenogranite foliated to gneissic plutons. Marble tectonic breccias occur locally.

The map pattern of Black Donald domain is dominated by slivers of different metasedimentary and metaplutonic rocks that are folded into large interference fold structures (*see* Map P.3443). This is in contrast to the more belt-like pattern present within Mazinaw domain. In addition, at least in the synoptic area, gabbroic rocks of the Killer Creek Suite are absent from Black Donald domain, and the abundance of Methuen Suite granitic rocks is greatly reduced within Black Donald domain. In addition, in Mazinaw domain, Methuen Suite granitic rocks are spatially associated with Elzevir Suite tonalitic rocks, whereas this association is less well developed or absent in Black Donald domain.

In the northwestern part of the synoptic area, Mazinaw domain is in contact with mafic metavolcanic and clastic metasedimentary rocks of Black Donald domain; however, as one goes farther to the east, Mazinaw domain is in contact with carbonate metasedimentary rocks of Black Donald domain. The domain boundary has been offset by northwest-trending faults cutting the area, which serves to move the domain boundary further northward as one heads to the east. The fact that domain boundary is in contact with different major rock units along its length, and that it is offset significantly by the near-vertical later faults in the area, suggest that the boundary is a low- to moderate-angle feature, possibly a thrust fault. Offset of the domain boundary across the northwest faults also explains why Schwerdtner, Serafini and Burke (2004) placed the boundary in the Lucky Lake area, whereas Easton (1992c) had indicated the boundary occurred on the northern shore of Round Schooner Lake.

Mazinaw–Black Donald Domain Boundary

In the Wensley area, the boundary between the Mazinaw domain and the Black Donald domain is marked by a 250 to 750 m thick zone of straight gneisses of intermediate composition. These straight gneisses bound the northern margin of the Abinger Granite, and are probably derived from tonalitic and granitic rocks found south of the boundary and paramphibolites found to the north. The straight gneisses are older than the regional metamorphic event within Mazinaw domain that affects the Flinton Group (M_2, *see* "Metamorphism") as flattened quartz lenticles within the straight gneisses have been recrystallized into equant quartz grains. Recrystallization has also increased the mean grain size of the straight gneisses, although the thinly laminated character of these rocks still persists. The straight gneisses dip to the northwest at 25 to 30°, and most units within the Black Donald domain dip shallowly to the northwest. The boundary can be traced from the Wensley area into the Palmerston Lake area; however, the boundary is offset to the northwest by Paleozoic-age faulting as one proceeds from west to east (*see* Map P.3443).

From west to east, the boundary cuts across different rock types within Mazinaw domain. In the extreme west, it places granitic gneisses of the Mazinaw domain against amphibolites of the Black Donald domain; moving east, the boundary juxtaposes Mazinaw domain tonalite orthogneisses against amphibolites and metawackes; farthest east, Mazinaw domain tonalite paragneiss is in contact with marble. In the Wensley area, metamorphic grade appears to be higher on the Bancroft terrane side of the boundary. However, near Round Schooner Lake (Palmerston Lake area), metamorphic grade drops rapidly to the northwest with increasing distance from the terrane boundary. Here, marbles are massive and coarse grained at 500 m north of the boundary, but by 750 m north of the boundary, they are medium grained and preserve bedding (likely transposed). This suggests that M_2 metamorphism in the western terrane overprinted the domain boundary, and that the boundary may have been established as early as 1160 Ma.

Robertson Lake Mylonite Zone

The eastern boundary of the Mazinaw domain with the Sharbot Lake domain to the east generally lies 10 to 15 km east of the eastern boundary of the synoptic area; however, this boundary does sweep westward toward the southeast corner of the synoptic area (*see* Figures 2 and 3). This boundary is an east- to southeast-trending, moderately dipping shear zone, termed the Robertson Lake mylonite zone (Smith 1958; Jackson 1980; Carter 1981; Easton 1988; Busch, van der Pluijm and Essene 1994; Busch et al. 1994). As was the case for the Mooroton shear zone, regional lithologic and metamorphic contrasts are present across the Robertson Lake zone. These include

1. a lithologically less diverse mafic metavolcanic–marble sequence on the Sharbot Lake side of the boundary
2. slightly higher metamorphic temperatures (+50°C) and much higher metamorphic pressures (2 to 3 kilobars) on the Mazinaw side of the boundary (Busch, van der Pluijm and Essene 1994; Busch et al. 1994); and
3. lower $^{40}Ar/^{39}Ar$ cooling ages (940 Ma versus 1040 Ma) on the Mazinaw side (Busch, van der Pluijm and Essene 1994; Busch et al. 1994)

These metamorphic conditions are analogous to the differences observed across the Mooroton shear zone, and attest to the distinctive geologic history of the Mazinaw domain compared to adjacent terranes and domains. It is because of this distinctive geologic history and bounding shear zones that the Mazinaw domain is considered a terrane, not a domain, in Easton (1992b).

Mazinaw Domain

OVERVIEW

Mazinaw domain consists of a series of alternating, northeast-trending, metaplutonic and supracrustal belts (Figures 2, 3, 4 and 5). Two main supracrustal belts are present within the exposed part of the terrane: one in the Clare River structure south of the synoptic area and the other in a belt extending from Cloyne through Plevna through Ompah within the synoptic area (*see* Figure 3). Based on a preliminary analysis of the synoptic area, Easton (1992b) suggested that the synoptic area could be divided into 3 northeast-trending belts based on varied rock types (*see* Figure 4). From north to south, these are

1. a northern metaplutonic belt, dominated by earlier metatonalitic and metagranodioritic metaplutonic rocks, younger metagranites (including the Abinger and Norway Lake granites), and a younger bimodal succession of tholeiitic metavolcanics (Mazinaw Lake Formation). The Shabomeka shear zone marks the boundary between the northern metaplutonic belt and the central supracrustal belt.

2. a central supracrustal belt, dominated by calc-alkalic metavolcanic rocks (Kashwakamak Formation and equivalents to the northeast) and siliciclastic and carbonate metasedimentary rocks.
3. a southern metaplutonic belt, dominated by metatonalitic and metagranodioritic plutonic rocks of the Cross Lake–Northbrook plutons. It is unclear if the Addington Granite constitutes the southern part of this belt or is a separate belt.

Flinton Group strata occur locally in all 3 belts. Easton (1992b) noted that the contact relationships between the 3 belts are obscure, and may consist of a variety of structures, ranging from early refolded thrusts to later shear zones (*see* "Structural Geology").

In contrast to this lithological subdivision, a tectonostratigraphic approach suggests that within the synoptic area, the Mazinaw domain may be more realistically divided into 2 tectonic elements (*see* Figure 5). An "arc"-dominated succession in the south, and a "rifted-arc" succession in the north, with the Fernleigh belt marking the approximate boundary between them (*see* Figure 5). The "arc" succession constitutes 1275 million-year-old calc-alkalic metavolcanic and metasedimentary rocks that were intruded

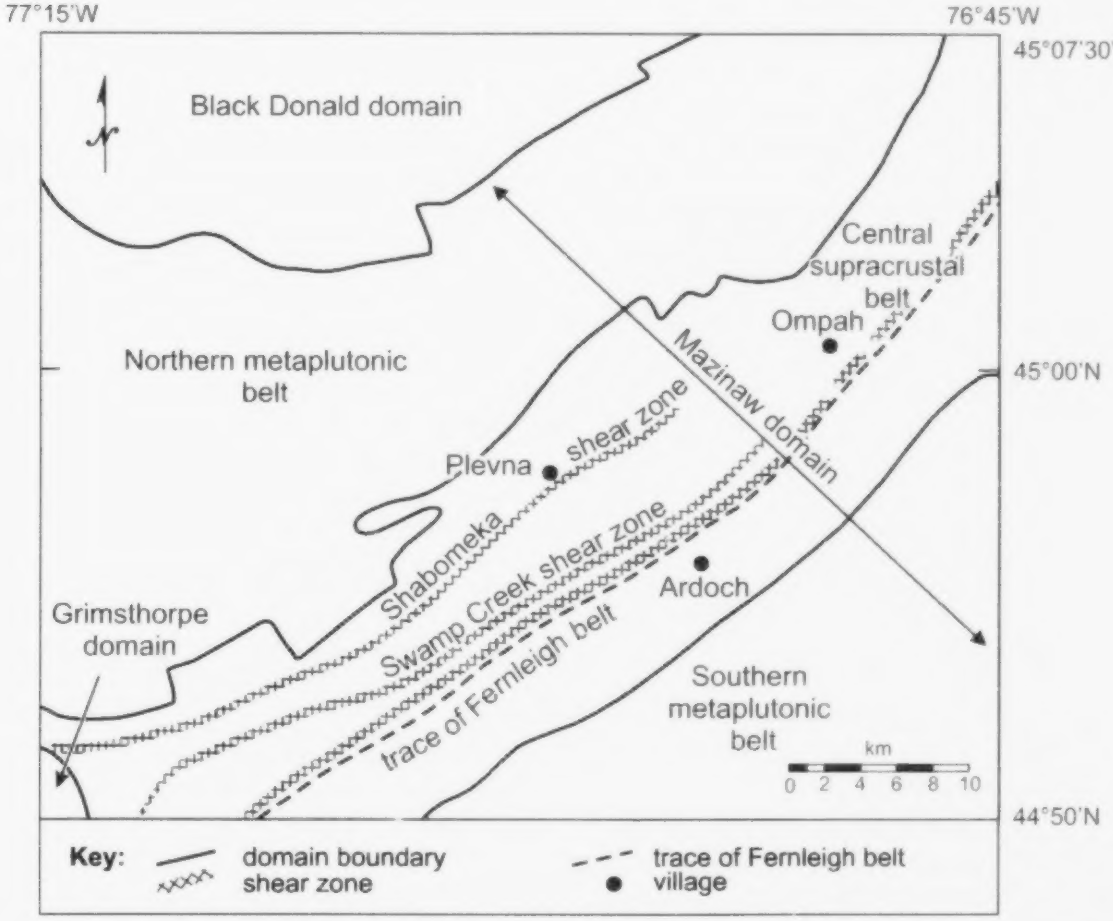
77°15'W
76°45'W
45°07'30"N
45°00'N
44°50'N
Black Donald domain
Northern metaplutonic belt
Central supracrustal belt
Ompah
Mazinaw domain
Plevna
Shabomeka shear zone
Swamp Creek shear zone
trace of Fernleigh belt
Ardoch
Grimsthorpe domain
Southern metaplutonic belt
km
0 2 4 6 8 10
Key:
domain boundary
shear zone
trace of Fernleigh belt
village

Figure 4. Simplified geological map of the synoptic area showing the main belts of metaplutonic and supracrustal rocks.

by the Northbrook–Cross Lake batholith at circa 1250 Ma. The "rifted-arc" succession comprises tholeiitic metavolcanic and related metasedimentary rocks that are intruded by Methuen Suite granites and Lavant Suite gabbros, all emplaced at circa 1245 Ma. Under this tectonostratigraphic approach, the central supracrustal belt consists of 2 different supracrustal sequences, and the northern and southern metaplutonic belts are simply pluton-rich portions of the rifted-arc and arc successions, respectively.

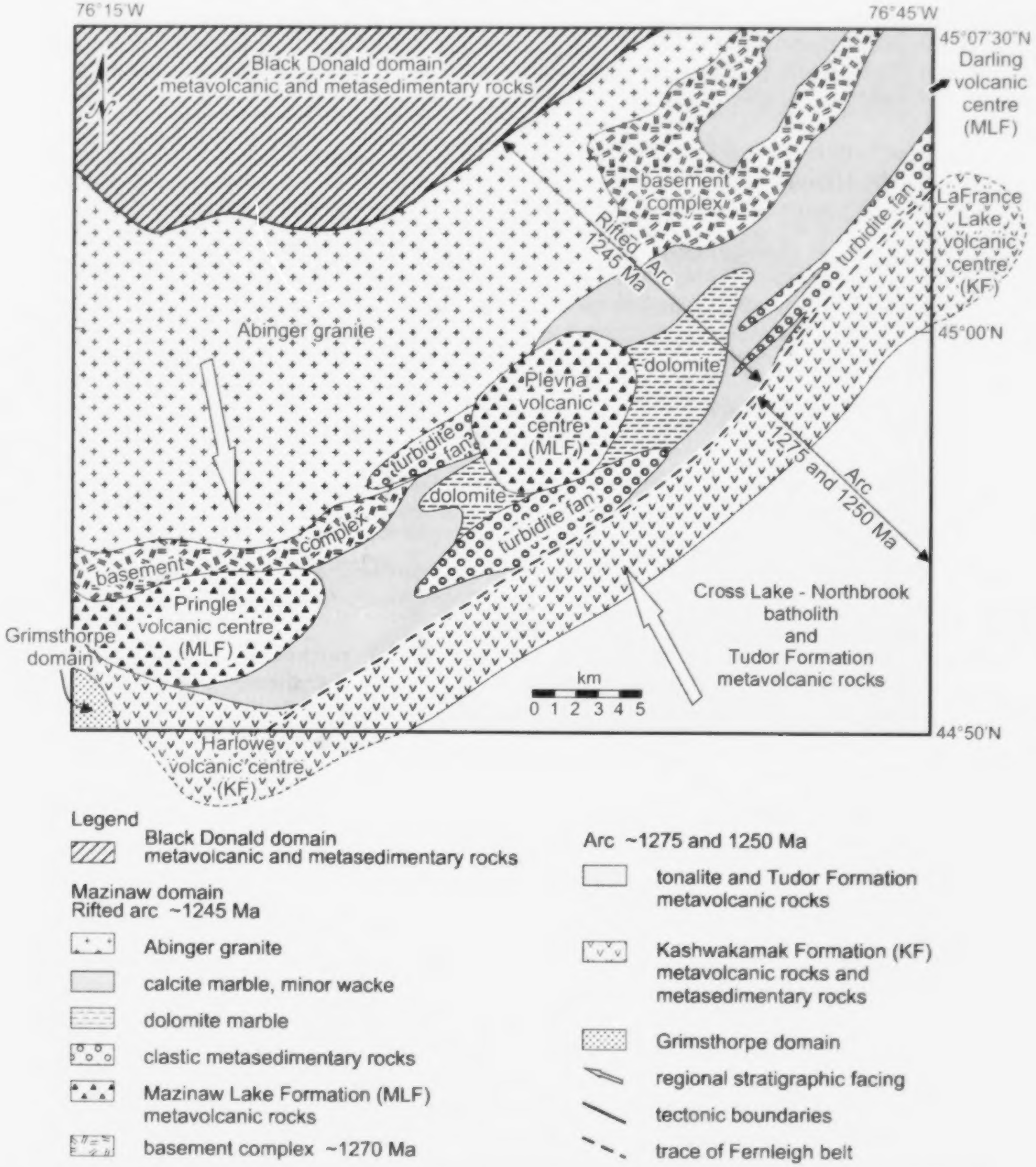
76°15'W
76°45'W
45°07'30"N
45°00'N
44°50'N
Black Donald domain
metavolcanic and metasedimentary rocks
Darling volcanic centre (MLF)
basement complex
LaFrance Lake volcanic centre (KF)
Rifted Arc 1245 Ma
turbidite fan
Abinger granite
dolomite
Plevna volcanic centre (MLF)
turbidite fan
dolomite
turbidite fan
1275 and 1250 Ma Arc
basement complex
Pringle volcanic centre (MLF)
Grimsthorpe domain
Cross Lake - Northbrook batholith and Tudor Formation metavolcanic rocks
km
0 1 2 3 4 5
Harlowe volcanic centre (KF)
Legend
Black Donald domain metavolcanic and metasedimentary rocks
Mazinaw domain
Rifted arc ~1245 Ma
Abinger granite
calcite marble, minor wacke
dolomite marble
clastic metasedimentary rocks
Mazinaw Lake Formation (MLF) metavolcanic rocks
basement complex ~1270 Ma
Arc ~1275 and 1250 Ma
tonalite and Tudor Formation metavolcanic rocks
Kashwakamak Formation (KF) metavolcanic rocks and metasedimentary rocks
Grimsthorpe domain
regional stratigraphic facing
tectonic boundaries
trace of Fernleigh belt

Figure 5. Interpretative geological map of the synoptic area, showing the location of major volcanic centres and sedimentary depocentres, as well as areas of possible basement.

Table 3. Summary of tectonic setting and source rocks for the Flinton Group in the synoptic area.

Tectonic Setting	Flinton Group Unit and Location	Source Based on Geological Location	Source Based on Detrital Zircons or Geochemistry	Direction of Transport Based on Where Unit is Preserved
Rifted Arc	Norway Lake metaconglomerate and pelite	Methuen Suite granites, Killer Creek gabbros, Mazinaw Lake Formation metavolcanic rocks	Conglomerate and metapelite have geochemical signature of Methuen Suite and Mazinaw Lake Formation rocks. No zircon data	To north and east
	Myer Cave Formation metapelite west of Plevna	Mazinaw Lake Formation metavolcanic rocks and Grenville Supergroup metasedimentary rock	Calcareous matrix consistent with volcanic and carbonate source. No zircon data.	To north, possibly west
	south of Plevna, marble clast metaconglomerate	Grenville Supergroup metasedimentary rocks	Calcareous character consistent with adjacent country rocks	Unknown
	Grindstone Lake, metaconglomerate with carbonate matrix	Marble, Methuen Suite granite	No data	To north
	Little Green Lake, muscovite-rich metapelites	Grenville Supergroup metasedimentary rocks	No data	Unknown
	Mosque Lake area, Myer Cave and Bishop Corners Formation metapelite and meta-arenite	Mazinaw Lake Formation metavolcanic rocks and Lavant Suite gabbros	Bishop Corners Formation metapelite derived from intensely weathered felsic metavolcanic rocks. Myer Cave Formation rocks have average crust signature. No zircon data.	Unknown, possibly to north and east
Arc	Ompah Formation metaconglomerate and meta-arenite, near Ompah and Sunday Lake	Kashwakamak Formation metavolcanic rocks and Grenville Supergroup metasedimentary rocks in the La France Lake area	Calcareous matrix consistent with volcanic and carbonate source. Zircon data inconclusive regarding a ~1245 or ~1275 source area.	To southwest
	Bishop Corners Formation metaconglomerate and meta-arenite near Bishop Corners and Ore Chimney Mine	Kashwakamak Formation metavolcanic rocks, Grenville Supergroup metasedimentary rocks, Cross Lake and Northbrook tonalite in the Big Gull Lake area	Mafic metavolcanic source (Tudor or Kashwakamak formations). Contains 1271 to 1299 Ma zircons, consistent with the age of the Kashwakamak Formation.	To southwest
Boundary between Arc and Rifted Arc	Fernleigh belt, includes Bishop Corners, Myer Cave and Fernleigh Formation metapelite and marble	Grenville Supergroup siliciclastic and carbonate metasedimentary rocks	Bishop Corners Formation metapelite derived from intensely weathered felsic metavolcanic rocks of the Kashwakamak Formation. Myer Cave and Fernleigh formations have average crust signature. No zircon data.	In Myer Cave area, possibly inward into belt from north and south. Unknown for other parts of the belt.

On a regional scale, the rifted-arc succession is south facing, consisting of a gabbro-amphibolite-tonalite basement cut by granite, that is overlain by Mazinaw Lake Formation metavolcanic rocks that, in turn, interfinger with or are overlain by siliciclastic and carbonate metasedimentary rocks. Volcanic centres in the rifted-arc succession are present north of Cloyne, near Plevna, and near Flower Station, in the Darling area located to the northeast of the synoptic area (*see* Figure 5). Metasedimentary rocks in the rifted arc differ from those present in the arc succession in that the rifted arc contains possible stromatolite-bearing dolomite marbles (overall, dolomitic marble is more abundant in the rifted-arc than in the arc succession), and more turbiditic siliciclastic rocks.

In contrast, the arc succession is north facing on a regional scale, consisting of Tudor Formation low-potassium tholeiitic metavolcanic rocks overlain by calc-alkalic Kashwakamak Formation metavolcanic rocks. The later interfinger with or are overlain by siliciclastic and carbonate metasedimentary rocks. Emplacement of the Northbrook–Cross Lake batholith appears to have been localized at the contact between the Tudor and Kashwakamak formations. Volcanic centres related to the arc are located in the Harlowe–Nervine Lake area and near La France Lake (*see* Figure 5).

Distribution and composition of Flinton Group strata varies depending on whether it lies on rocks of the rifted-arc or the arc succession. In the rifted arc, Flinton Group rocks are very patchy in their distribution, and consists mainly of metapelite and locally derived conglomerate (Table 3). Where present, Flinton Group strata occur around intrusions or volcanic centres that conceivably would have been topographic highs during Flinton Group sedimentation. If the current distribution of Flinton Group rocks tells us anything about transport direction, then these rocks are generally found north and east of the inferred highs (*see* Table 3). The very regular distribution of patches of Flinton Group rocks in this region indicates that the group may once have been more widespread than current preservation might otherwise suggest (i.e., a thin veneer over much of the belt).

In contrast, in the arc, the Flinton Group is dominated by meta-arenite and metaconglomerate (Bishop Corners and Ompah formations). The Bishop Corners Formation is derived from the Harlowe volcanic centre, whereas the Ompah Formation from the La France–Sunday Lake volcanic centre (*see* Figure 5). As summarized in Table 3, geochemistry and detrital zircon data support this suggestion. This

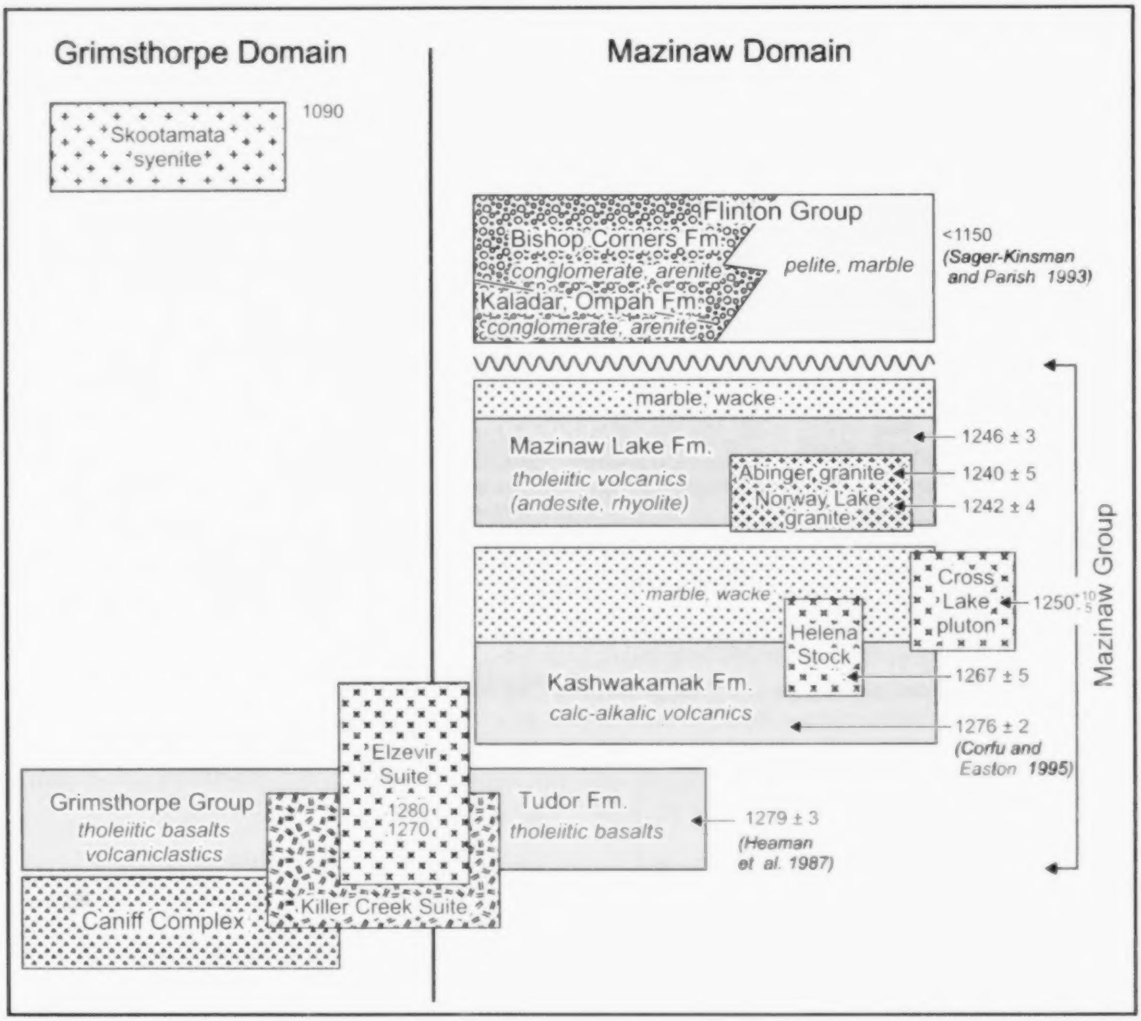
Grimsthorpe Domain
Mazinaw Domain
Skootamata 'syenite'
1090
Flinton Group
Bishop Corners Fm.
conglomerate, arenite
Kaladar, Ompah Fm.
conglomerate, arenite
pelite, marble
<1150
(Sager-Kinsman and Parish 1993)
marble, wacke
Mazinaw Lake Fm.
tholeiitic volcanics
(andesite, rhyolite)
Abinger granite
Norway Lake granite
1246 ± 3
1240 ± 5
1242 ± 4
marble, wacke
Cross Lake pluton
1250 +10 -5
Helena Stock
Kashwakamak Fm.
calc-alkalic volcanics
1267 ± 5
1276 ± 2
(Corfu and Easton 1995)
Mazinaw Group
Elzevir Suite
1280
1270
Grimsthorpe Group
tholeiitic basalts
volcaniclastics
Tudor Fm.
tholeiitic basalts
1279 ± 3
(Heaman et al. 1987)
Caniff Complex
Killer Creek Suite

Figure 6. Stratigraphic framework present within the synoptic area, along with U/Pb age constraints on timing of deposition and/or emplacement.

interpretation also suggests that the Bishop Corners Formation and Ompah Formation meta-arenites and metaconglomerates have more similarities than differences from one another. In addition, if current distribution of Flinton Group strata in the arc tells us anything about transport direction, then these rocks are generally found southwest of the inferred sources, suggesting a similar transport direction. This is the opposite of transport directions that are inferred from the rifted arc.

As illustrated in Figures 4 and 5, the Fernleigh belt of Flinton Group rocks coincides with the proposed boundary between the arc and the rifted arc. This is logical, as one might expect that a previously formed tectonic boundary would be a topographic low where marine or lacustrine sediments could accumulate. Furthermore, local steep relief along this boundary could have been responsible for mass-wasting that led to the formation of the Myer Cave megabreccia.

STRATIGRAPHY

Major rock units within the synoptic area include, from oldest to youngest (Figure 6):

1. A basement complex present only in the northern metaplutonic belt of Mazinaw domain, containing Grimsthorpe domain type rocks, including Killer Creek-type gabbroic rocks, and tonalitic intrusion breccias including mafic metavolcanic and metasedimentary rocks and Killer Creek-type gabbroic rocks. This basement complex is preserved as thin lenses within the Abinger Granite.
2. Basalt-andesite-dacite-rhyolite metavolcanics of the Kashwakamak Formation of calc-alkalic affinity and minor tonalite intrusions (Moore and Morton 1986; Condie and Moore 1977; Harnois and Moore 1988), which have been dated using zircons at 1276 to 1270 Ma (Corfu and Easton 1995). The calc-alkalic metavolcanics overlie a slightly older, undated, mafic, tholeiitic metavolcanic sequence referred to as the Tudor Formation (Sethuraman and Moore 1973; Moore and Morton 1986; Harnois and Moore 1991). The bulk of the siliciclastic metasedimentary rocks and calcitic and dolomitic marbles in the area interfinger with, or received detritus from this volcanic sequence, and are designated herein as the Mississagagon Formation (Table 4).
3. Metatonalite and metagranodiorite intrusions of approximately 1250 Ma age (Corfu and Easton 1995) of the southern and northern metaplutonic belts within the synoptic area, including the Cross Lake tonalite.
4. A sequence of bimodal tholeiitic metavolcanic rocks (Mazinaw Lake Formation of Ayer (1979) and Easton and Ayer (1994)) and related fine- to medium-grained, heterogeneous granitic rocks (Abinger and Norway Lake granites in the map area, *see* Figure 6), all of which have been dated at 1245 to 1240 Ma (Corfu and Easton 1995). Siliciclastic metasedimentary rocks likely representing turbidite-fan systems collecting debris from the volcanic centres, as well as calcitic and dolomitic marbles are associated with this younger volcanic sequence. These metasedimentary rocks are included within the Mississagagon Formation, even though they may be younger, simply because of the difficulty in determining the relative age of metasedimentary rocks within the synoptic area.
5. The Flinton Group, deposited at circa 1157±10 Ma (maximum age of deposition, Sager-Kinsman and Parrish 1993), which unconformably overlies all older rock units.

Table 4. Stratigraphic usage in this report.

Stratigraphic Unit	Age (in Ma)	Subunits
Flinton Group (Moore and Thompson 1972, 1980; F.D. Ford, personal communication of unpublished data, 1992)		
Fernleigh Formation laminated calcareous pelite to schist		
Myer Cave Formation pelite and schist, locally graphitic and sulphidic, calcite and dolomitic marble, marble clast breccia		megabreccia member unlaminated schist member calcite marble member laminated schist member dolomite marble member pelite member
Lessard Formation calcareous pelite and schist		
Bishop Corners Formation matrix- to clast-supported conglomerates, both heterolithic and monolithic, cross-bedded arenite, muscovite-rich pelite to schist	<1157±10[6]	pelite member arenite-conglomerate member
Ompah Formation (Ford 1992; this study) matrix-supported, heterolithic conglomerate, mafic matrix; minor cross-bedded calcareous litharenite		conglomerate member litharenite member
Norway Lake Formation (this study) matrix-supported, heterolithic conglomerate, minor litharenite		
Grenville Supergroup, Mazinaw Group (Easton 1992b) (includes only the supracrustal units listed below)		
Ore Chimney Formation (Moore and Thompson 1972, 1980) regolith locally developed on underlying units, includes black biotite schist, pebbly schist		
Methuen intrusive suite (Easton 1992b) monzogranite to syenogranite intrusions, including Abinger, Norway Lake and Addington granites	1245 to 1242[1, 2]	coeval with Mazinaw Lake Formation
Mazinaw Lake Formation (Ayer 1979) andesitic, rhyodacitic to rhyolitic, tholeiitic metavolcanic rocks, minor volcaniclastic metasedimentary rocks and marble	1246 to 1242[1]	
Elzevir plutonic suite (Easton 1992b) tonalite, trondhjemite and granodiorite intrusions, minor diorite; intrusion breccias common, both syn-and post-volcanic in age, includes Northbrook-Cross Lake tonalite, Elzevir tonalite, Helena stock	1275 to 1250[1, 3]	
Mississagagon Formation (new term) calcite and dolomite marble, calc-silicate, metawacke, minor metaconglomerate, intercalated siliceous clastic metasedimentary rocks and marble	1275 to 1255[1]	
Kashwakamak Formation (Harnois and Moore 1987, 1991) calc-alkalic basalt, andesite, dacite, rhyolite flows, pyroclastic deposits, volcanic domes and subvolcanic intrusions	1276±2[1]	
Tudor Formation (Lumbers 1967a, Sethuraman 1970) tholeiitic basalt, minor silicified basalt, andesite, volcaniclastic metasedimentary rocks	1279±3[4] >1282±3[5]	eastern member (Mazinaw domain) western member (Grimsthorpe domain)
basement complex consists of metabasalt and metagabbro of the Canniff Complex; volcaniclastic metaconglomerates and metasandstones of the Grimsthorpe Group, Killer Creek Suite metagabbroic rocks (Easton 1992b, Easton and Ford 1994a); and locally, older members of the Elzevir plutonic suite. Areally restricted to the northern part of the synoptic area	>1270[1, 3]	

[1] Corfu and Easton (1994, 1995); [2] van Breemen and Davidson (1988); [3] Lumbers et al. (1990); [4] Heaman et al. (1987); [5] Sager-Kinsman and Parrish (1993); [6] Easton and Kamo (2005).

A detailed stratigraphic framework has only been outlined in the Cloyne–Marble Lake area (*see* Figure 6; *see* Table 4), although, as illustrated in Figure 5, these major units can be traced, with reasonable certainty, throughout the synoptic area. In the case of the metavolcanic rocks, geochemical studies can be used effectively to discriminate between the 3 main metavolcanic formations recognized to date (*see* "Mazinaw Domain", "Geochemistry"). Prior to 1994, age relationships between the various formations had been determined primarily on the basis of structural analysis of the area and facing relationships (Figure 7); however, subsequent U/Pb zircon geochronology studies in the area (Corfu and Easton 1995) have firmly established the ages of the various formations (*see* Figure 6).

Stratigraphic usage in the area is summarized in Table 4, which has been compiled from several sources. Notable changes from previous usage include introduction of the term Mississagagon Formation to refer to Grenville Supergroup marbles and siliceous clastic metasedimentary rocks deposited coevally with, or shortly after deposition of, the Kashwakamak Formation. These rocks would have previously been considered to be part of the Mayo Group of Lumbers (1967a). In addition, there are refinements to the Flinton Group nomenclature, incorporating changes originally suggested by Ford (1992; and F.D. Ford, personal communication of unpublished data, 1992) and Easton and Ford (1991). Detailed explanations for these changes are presented in the section "Flinton Group" later in this report.

Ayer (1979)	Harnois & Moore (1991) Moore & Morton (1986)	this study	Age (Ma)
		diabase dikes	590
metadiabase dikes	Flinton Group ∿ ∿ Ore Chimney Formation ∿∿∿	Flinton Group ∿ ∿ Ore Chimney Formation ∿∿∿ metadiabase dikes	1150-1030
granite plutons marble and metawacke calc-alkalic metavolcanics (i.e. Kashwakamak Fm.) marble and metawackes ∿ ∿	metagranites and metatonalites marble, wacke ∿ ∿	Methuen Suite granites minor metasediments ∿ ∿	1240
Mazinaw Lake Fm. andesitic to rhyolitic tholeiitic metavolcanics metavolcanics	Mazinaw Lake Fm. / Kashwakamak Fm. andesite-rhyolite / basalt-dacite tholeiitic / calc-alkalic metavolcanics / metavolcanics	Mazinaw Lake Fm. andesite-rhyolite tholeiitic metavolcanics ∿∿∿	1240
∿ ∿	∿ ∿ minor metawacke, metatuff, marble	Elzevir Suite metatonalite marble, metawacke ∿ ∿	1250-1270
Tudor Fm. mafic tholeiitic metavolcanics	∿ ∿ Tudor Fm. mafic tholeiitic metavolcanics	Kashwakamak Fm. calc-alkalic metavolcanics ∿ ∿ Tudor Fm. mafic tholeiitic metavolcanics	1276

∿∿∿ major unconformity

∿ ∿ disconformity, unconformity

Figure 7. Correlation chart, showing evolution in stratigraphy within the synoptic area. Changes in stratigraphy are largely based on U/Pb age constraints on timing of deposition and/or emplacement obtained by Corfu and Easton (1995).

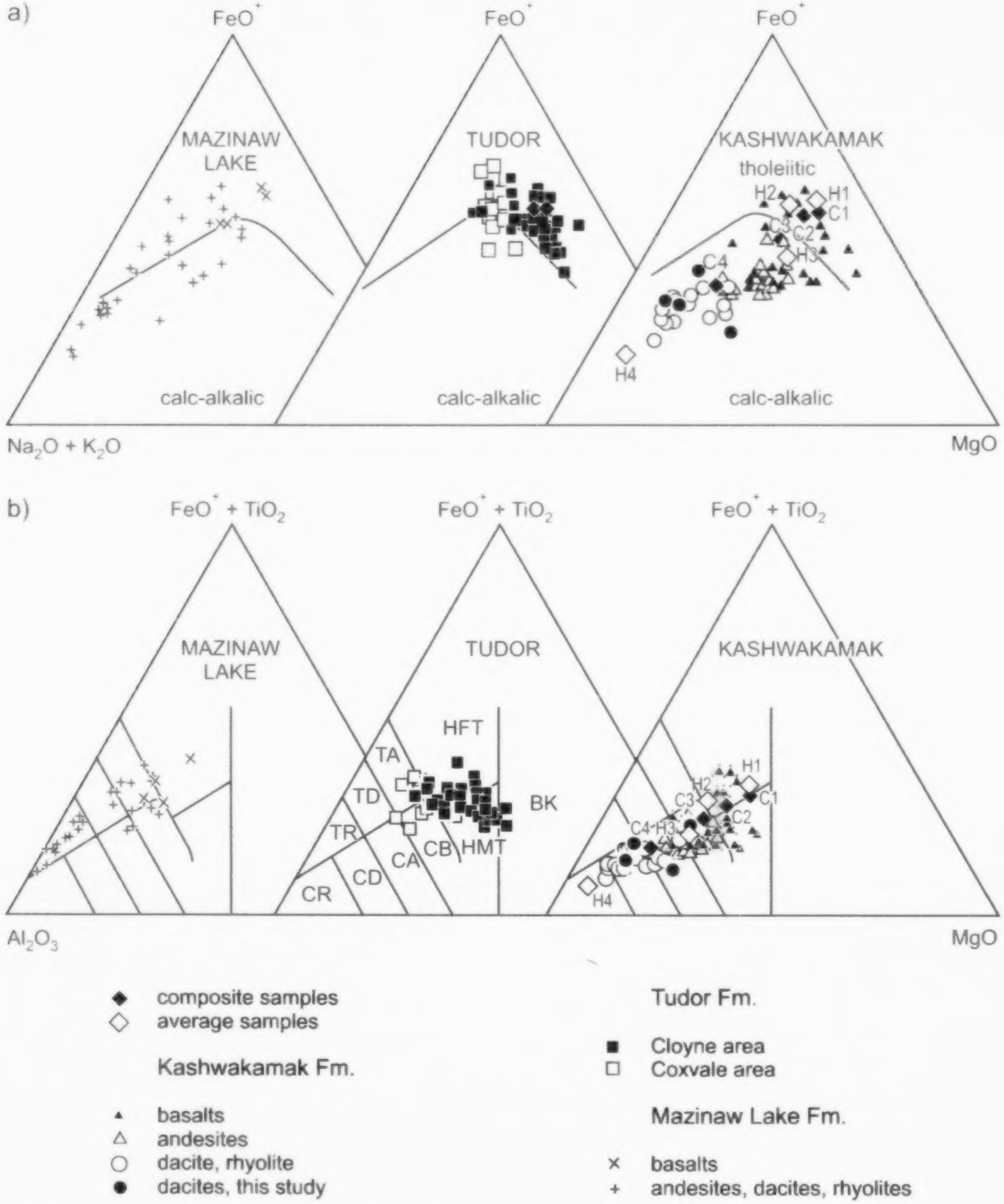

Figure 8. a) Alkalis–iron–magnesium (AFM) diagram for metavolcanic rocks from the Mazinaw Lake, Tudor and Kashwakamak formations. b) Jensen (1976) diagram for metavolcanic rocks from the Mazinaw Lake, Tudor and Kashwakamak formations. See text for reference sources. Field abbreviations: BK, basaltic komatiite; CA, calc-alkali andesite; CB, calc-alkali basalt; CD, calc-alkali dacite; CR, calc-alkali rhyolite; HFT, high-iron tholeiite; HMT, high-magnesium tholeiite; TA, tholeiitic andesite; TD, tholeiitic dacite; TR, tholeiitic rhyolite.

GEOCHEMISTRY

Several geochemical studies have been conducted within the Cloyne–Marble Lake area, including Sethuraman (1970), Sethuraman and Moore (1973), Condie and Moore (1987), Ayer (1979), Harnois (1988a), Harnois and Moore (1991), and Easton and Ayer (1994). The studies of Baragar (1972) and Moore and Morton (1986) largely involved reprocessing of data from previous studies, mainly Sethuraman (1970). In addition, major element data was collected on metavolcanic rocks from the Coxvale area (Ardoch map area) by Mannard (1982). Representative data from the Palmerston Lake and Mazinaw areas were also collected during the course of this study. All of these data were combined during the course of this study to provide improved characterization of the major metavolcanic packages within the synoptic area. Results are described in greater detail in subsequent parts of this report; however, it is necessary to summarize the geochemistry of the metavolcanic rocks here because of its significance in terms of unravelling the regional stratigraphy. The data for the Cloyne–Marble Lake area are summarized in Figures 8a, 8b, 9a, 9b, 10 and 11. Major element data are emphasized, because not all data sets included trace element analyses, and for those that did, a uniform set of key trace elements is not present.

Figure 8a shows alkalis–iron–magnesium (AFM) diagrams for the 3 major metavolcanic formations in the Cloyne–Marble Lake area. The Mazinaw Lake Formation shows considerable scatter, in part because of the difficulties in assigning rocks in the Pringle Lake area to either the Mazinaw Lake or Tudor formations. In addition, some volcaniclastic metasediments might be included in the Mazinaw Lake Formation data set. Both the Tudor and Kashwakamak formations show distinct groupings, with only limited scatter, even though no alteration screen has been applied to the data portrayed in Figure 8a. In the case of the Tudor Formation, rocks from the Coxvale area overlap those from the Cloyne–Northbrook area.

Figure 8b, a Jensen diagram, shows similar trends, highlighting the tholeiitic character of the Tudor and Mazinaw Lake formations, and the calc-alkalic signature of the Kashwakamak Formation. This is further illustrated in Figure 9a, a Miyashiro (1974) diagram.

Figure 9b, a Mullen (1983) diagram, contains fewer analyses because it includes a silica cutoff (45% to 54% SiO_2). The Mullen diagram suggests that the Mazinaw Lake Formation basalts and icelandites may have formed in a different tectonic environment than the Tudor Formation basalts. In addition, 2 geographically distinct clusters may be present in the Tudor Formation. One cluster, containing samples located east of the Mooroton shear zone, including the Coxvale samples, may represent an island-arc tholeiite (IAT) to calc-alkalic basalt (CAB) clan, and is located near the centre of the diagram (*see* Figure 9b). The other cluster, containing samples located west of the Mooroton shear zone, is offset toward the MnO apex, but still lies within the island-arc tholeiite field. This geographic distinction is not discernable on the other major element plots. The Tudor Formation data set, which mostly contains data from Stehuraman (1970), does not include high quality trace element data to further test the significance of this possible geochemical difference across the Mooroton shear zone. Limited rare earth element data

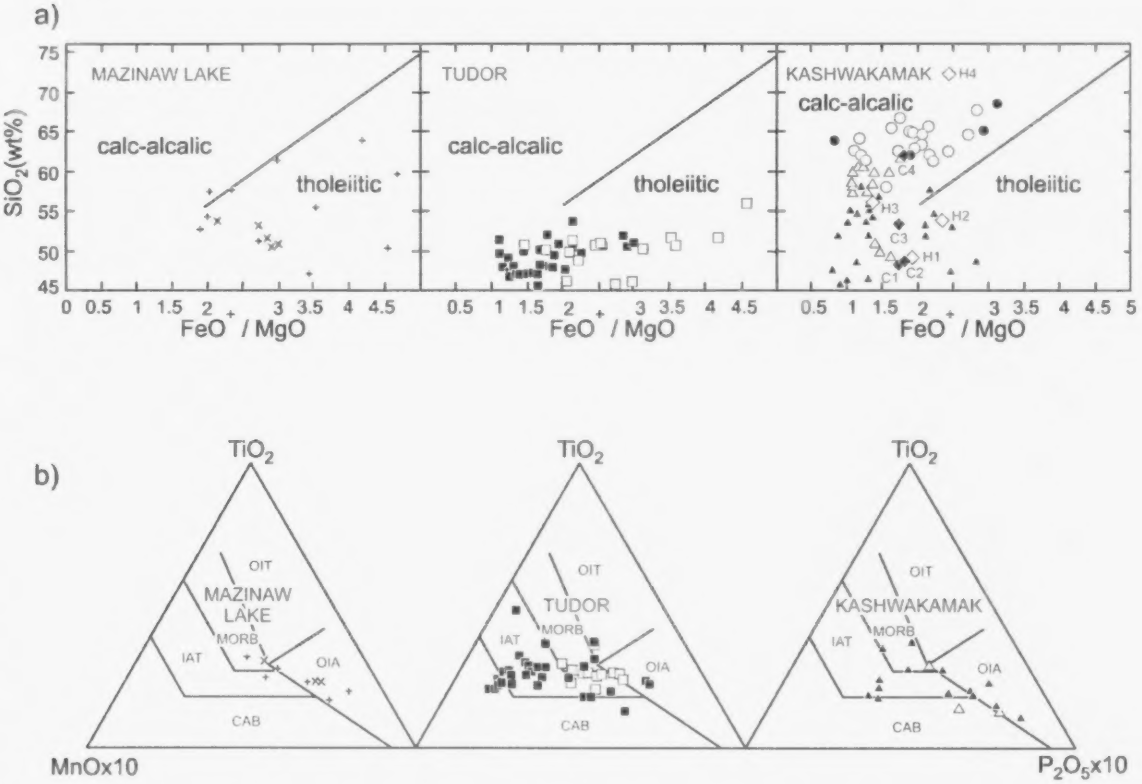

Figure 9. a) FeO total/MgO versus SiO_2 diagram (Miyashiro 1974) for metavolcanic rocks from the Mazinaw Lake, Tudor and Kashwakamak formations. b) MnO–TiO_2–P_2O_5 diagram (Mullen 1983) for metavolcanic rocks from the Mazinaw Lake, Tudor and Kashwakamak formations. See text for reference sources. Field abbreviations: CAB, calc-alkali basalt; IAT, island-arc tholeiite; MORB, mid-ocean ridge basalt; OIA, ocean island andesite; OIT, ocean island tholeiite.

presented by Harnois and Moore (1991), shown in Figure 10, suggest that Tudor Formation basalts west of the Mooroton shear zone show greater light rare earth element depletion, and lower total abundances, consistent with them being N-MORB. In contrast, basalts east of the Mooroton shear zone have flatter rare earth element patterns and higher total rare earth element contents. Insufficient data is available to more precisely compare the possible tectonic settings of these two basalt groupings, however, these geochemical distinctions may be important in subsequent geochemical mapping of the Tudor Formation.

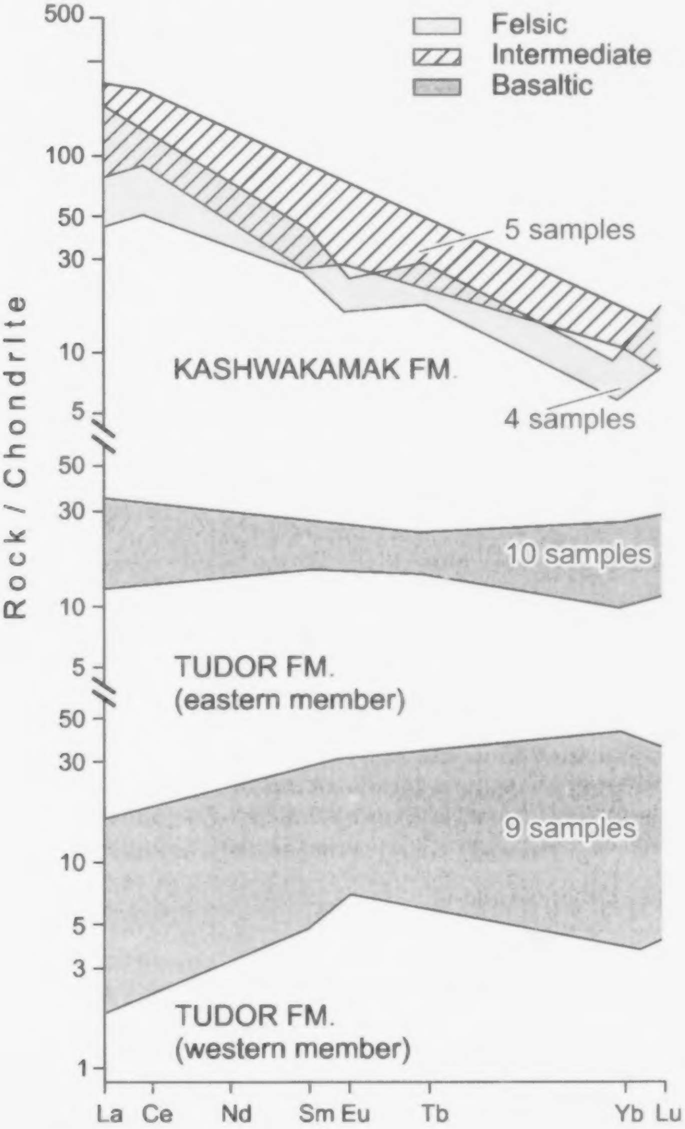

Figure 10. Rare earth element data for metavolcanic rocks from the Mazinaw Lake, Tudor and Kashwakamak formations. See text for discussion.

High-quality trace element data were obtained from the Mazinaw Lake and Kashwakamak formations during this study. Rare earth element plots illustrate the unique patterns present between the Mazinaw Lake and Kashwakamak formations (Figure 11a). The Kashwakamak Formation shows patterns typical of calc-alkalic suites, with felsic end-members showing heavy rare earth element (HREE) depletion and limited europium anomalies (*see* Figure 11a, sample 93RME-0011). The results obtained for the Kashwakamak Formation from this study are similar to the data obtained by Harnois and Moore (1991). In contrast, the Mazinaw Lake Formation samples have much higher HREE contents, and prominent negative europium anomalies (*see* Figure 11a, samples 93RME-0014, 91RME-0021, 91RME-1023, 91RME-1114). The results from the Mazinaw Lake Formation are consistent with the major element data originally obtained by Ayer (1979). They are significant in showing the geochemical similarity between the Mazinaw Formation metavolcanics and the Abinger and Norway Lake granites (*see* Figure 11b), as well as being similar to Archean FIII rhyolite-icelandite suites that host volcanogenic massive sulphide (VMS) deposits (*see* Figures 11b and 11c, Kamiskotia rhyolites and icelandites). The significance of the later relationship to exploration is explored more fully in "Economic Geology" and in Easton and Ayer (1994).

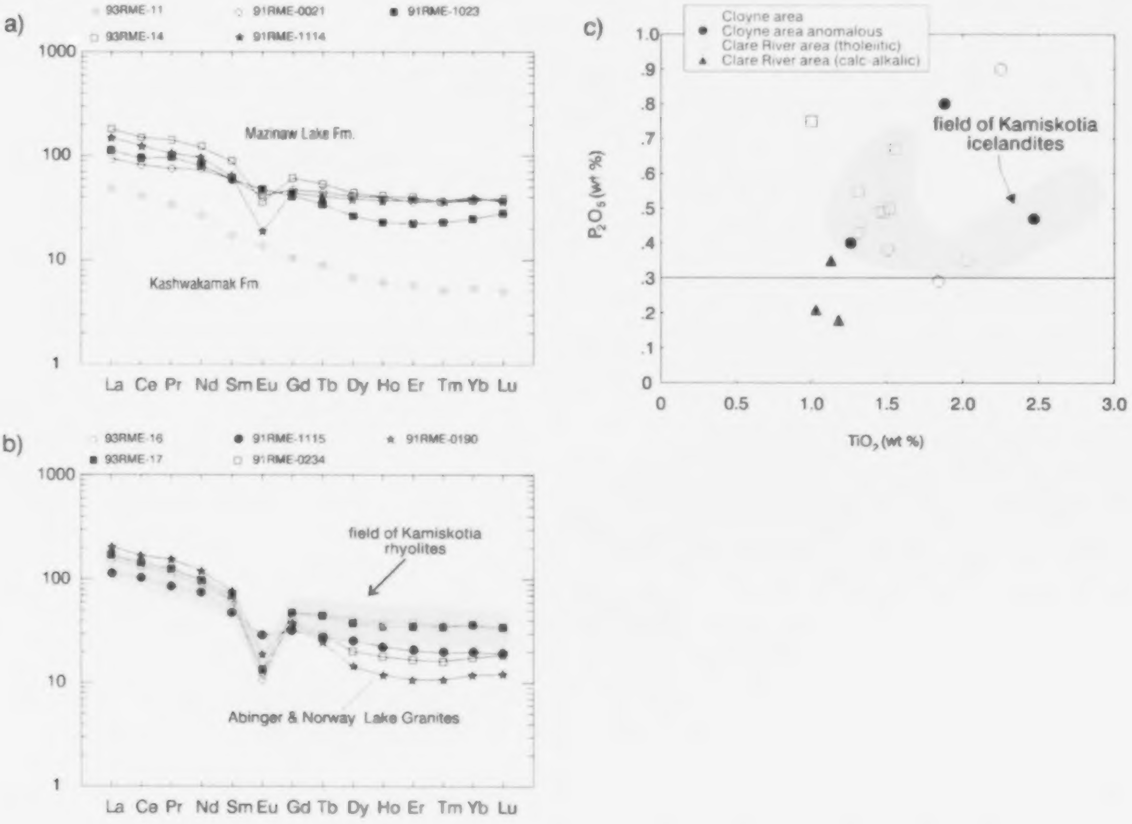

Figure 11. a) Chondrite-normalized rare earth element patterns for intermediate to felsic metavolcanic rocks in the Cloyne area. Sample 93RME-0011 is a typical Kashwakamak Formation metadacite. Metatonalite and metagranodiorite from the area have rare earth element patterns similar to the Kashwakamak Formation. Sample 91RME-0021 is a meta-icelandite of the Mazinaw Lake Formation. Other samples are metadacite and metarhyolite of the Mazinaw Lake Formation. b) Chrondrite-normalized rare earth element patterns for syenogranite plutonic rocks intrusive into the Mazinaw Lake Formation. Note similarity to the metavolcanic rocks of the Mazinaw Lake Formation. Also shown is the range of Kamiskotia area Archean metarhyolites *from* Lesher et al. (1986). c) TiO_2 versus P_2O_5 plot of rocks mapped as andesites from the Cloyne and the Clare River areas (data of Chappell 1978 and Bright 1986). Icelandites generally have P_2O_5 contents over 0.3 weight %. All Cloyne area samples are classed as tholeiites on both Irvine and Baragar (1971) and Jensen (1976) classification diagrams. "Anomalous" Cloyne area samples have silica contents either 2% lower or 1% higher than typical andesites (53 to 63% SiO_2).

Grouping of most marbles and siliceous clastic metasedimentary rocks in the area into the Mississagagon Formation is based, in part, on the results of the geochronological studies conducted in the area (Corfu and Easton 1995); but also on the study of new (this study) and previously published (Grant, Papertzian and Kingston 1989) geochemical analyses on these rocks. Both data sets suggest that the bulk of the pre-Flinton Group metasedimentary rocks in the synoptic area were deposited either syn- or shortly post-deposition of the Kashwakamak Formation, but prior to intrusion of various members of the Elzevir plutonic suite (both the 1267±5 Ma Helena stock and the $1250^{+10}/_{-5}$ Ma Cross Lake tonalite cut Mississagagon Formation marbles) and eruption of the Mazinaw Lake Formation. Chondrite-normalized rare earth element plots of analyses of Mississagagon Formation siliceous clastic and carbonate metasedimentary rocks show patterns similar to those obtained from the Kashwakamak Formation metavolcanics. No sampled metasedimentary rock showed patterns similar to those found for the Mazinaw Lake Formation. Given the distinctive rare earth element and other geochemical signatures of the Mazinaw Lake Formation and Methuen plutonic suite rocks, if these rocks were a significant provenance region for the metasedimentary rocks (apart from the age discrepancy), then this should be recognizable in the geochemistry of the metasedimentary rocks.

The Flinton Group overlies Grenville Supergroup rocks in the synoptic area. There is now consensus that the Flinton Group unconformably overlies older supracrustal and metaplutonic rocks (Moore and Thompson 1972, 1980; Thompson 1972; Smith 1958; Easton and Ford 1991). Recent U/Pb geochronology on detrital zircons from quartz arenite of the Bishop Corners Formation of the Flinton Group (Kinsman and Parrish 1990; Sager-Kinsman and Parrish 1993) support Moore and Thompson's (1980) separation of the Flinton Group from the Grenville Supergroup and the fact that it is significantly younger (by almost 100 Ma) than the Grenville Supergroup in the synoptic area.

As noted originally by Moore and Thompson (1972, 1980), the basal units of the Flinton Group show evidence of local provenance control on their mineralogy and chemistry, as subsequently documented herein. In addition, a regolith (Ore Chimney Formation) is present at the base of Flinton Group, which also shows a wide range in composition depending on its substrate (Harnois and Moore 1988). These effects are most apparent in the Marble Lake area, where metamorphic grade is lowest. As grade increases to the northwest, the unconformable nature of the Flinton Group becomes more difficult to establish, even though the major stratigraphic units can still be recognized in the field, based on their bulk composition and mineralogy, as confirmed by subsequent geochemical studies.

As noted in Table 4, Ford (1992; and F.D. Ford, personal communication of unpublished data, 1992) and Easton and Ford (1991) have suggested some modification of the Flinton Group stratigraphy proposed by Moore and Thompson (1972, 1980). These include

1. the recognition of 5 members within the Myer Cave Formation
2. division of the Bishop Corners Formation into a pelite and an arenite-conglomerate member, which may differ in both timing and environment of deposition, and
3. separation of conglomerates and litharenites in the Ompah–Palmerston Lake area into a new formation, the Ompah Formation, which may be older than the Bishop Corners Formation

The rationale for these modifications is detailed in the "Flinton Group". As discussed in that section, structural arguments suggest that the conglomerate- and arenite-dominated formations of the Flinton Group (Bishop Corners and Ompah formations) may be somewhat older, and deposited in a different setting than the pelite-dominated (pelite member, Bishop Corners Formation, Myer Cave and Fernleigh formations). These internal differences explain many of the confusing geological relationships described for different parts of the Flinton Group (e.g., Moore and Thompson 1972, 1980; Rivers 1976; Connelly 1985; Laing, Duke and Johnson 1987; Harnois and Moore 1988; Easton and Ford 1991; Ford 1992).

Table 5. Structural summary of the synoptic area.

Black Donald Domain	Northern Metaplutonic Belt, Mazinaw Domain	Central Supracrustal Belt, Mazinaw Domain
F_1-F_2 folds form Ramsay (1967) type 1 interference pattern (dome and basin) in the Norcan Lake area	F_1-F_2 folds form Ramsay (1967) type 1 interference pattern (dome and basin)	——
——	M_2 peak?	——
F_2 northeast-trending, broad folds	F_2 northwest-trending, tight, upright? Folds of gneissosity and rock units	F_3 northwest-trending, broad folds, shallow plunges
——	——	M_2 peak?
——	——	F_1-F_2 folds form Ramsay (1967) type 3 interference pattern
F_1 northeast-trending, tight folds of bedding?	F_1 northeast-trending, tight, recumbent folds of gneissosity and rock units	F_2 northeast-trending, tight upright folds
——	F_0 northeast-trending isoclinal folds, preserved within gneiss layers	F_1 northeast-trending, recumbent, isoclinal folds
Mazinaw-Bancroft terrane boundary formed	——	unconformity, Flinton Group deposited
Unknown	thrusting, shear zones form, M_1	thrusting, shear zone, M_1
Most units dip shallowly to the west and northwest	*most units dip moderately to the northwest*	*most units dip moderately to steeply to the southeast*

*All units appear to be deposited in areas located between volcanic or plutonic centres that were likely topographic highs during Flinton Group deposition

Geochemically, the Flinton Group strata, particularly the pelite-dominated members and formations, are distinctive from the Grenville Supergroup showing compositions typical of post-Archean shales. These differences also apply to the carbonate members, particularly the calcite marbles, which have compositions similar to those of the enveloping shales, and which show unusual enrichments in elements such as barium, strontium, and locally boron, consistent with deposition in an evaporitic environment (Easton 1995). These results and their metallogenic implications are detailed in the "Flinton Group" and "Economic Geology" sections.

STRUCTURE

The belt-like character of the synoptic area has been noted already (*see* Figure 5), and basically consists of a southern metaplutonic belt (Northbrook–Cross Lake metaplutons); a central supracrustal belt (Tudor, Kashwakamak, and Mississagagon formations and Flinton Group), and a northern metaplutonic belt (Abinger Granite, Mazinaw Lake Formation in the east). Based on the current geochronologic framework, these belts alternate in age of main magmatism: from circa 1250 Ma in the south, to circa 1265 to 1280 Ma in the centre, and to circa 1240 to 1250 Ma in age in the north. Explanations for this map pattern include thrust imbrication, with each different age rock package being separated by now cryptic thrusts; or an extremely folded landscape, with the younger successions deposited on or emplaced into the older rocks. The thrust scenario is currently favoured herein, as it best explains most aspects of the geology of the synoptic area.

The degree of pre-Flinton Group folding within the Grenville Supergroup is difficult to ascertain. Moore and Thompson (1972) and Thompson (1972) recognized 3 main folding events affecting the Flinton Group, as shown in Table 5, observations confirmed by subsequent studies (e.g., Rivers 1976; Karboski 1980; Jackson 1980; Anderson 1988; Easton 1992b; Ford 1992). More significantly in terms of map pattern interpretation is that the F_1 and F_2 folds produce interference patterns which differ between the different lithologic belts that comprise the synoptic area (*see* Table 5). Furthermore, recognition of fold generation and type (e.g., F_1 synform versus F_2 antiform) is not always possible on the basis of structural style alone (*see* Ford 1992), but typically requires knowledge of the local stratigraphy. Folds lacking Flinton Group strata are particularly difficult to assign to generation. As a consequence, the folds shown on Map P.3443 may differ in generation assignment and type from those shown on the maps of previous workers.

METAMORPHISM

The Mazinaw domain has been subjected to at least 2 regional metamorphic episodes. The first, M_1, reaching upper amphibolite and perhaps granulite facies locally, affected all rocks older than the Flinton Group, and was accompanied by intense deformation (D_1) which formed much of the penetrative fabric currently preserved in the rocks. D_1 was accompanied by thrusting and isoclinal folding which formed regional fold structures in the area, and is likely greater than 1160 Ma in age. The second metamorphic event (M_2) affected the Flinton Group, as well as all older rocks, and is circa 1020 Ma in age (Corfu and Easton 1995). The metamorphic pattern in the map area reflects M_2, with greenschist facies conditions (chloritoid-staurolite) present southeast of Marble Lake, rising to upper amphibolite (sillimanite) facies along the northern and eastern boundaries of the synoptic area. M_2 was accompanied by only localized deformation (shearing, minor folding, refolding of older structures) and was responsible for the growth of randomly oriented porphyroblasts (hornblende, microcline, staurolite, chloritoid, kyanite, tourmaline) in most rocks units.

Paleozoic Strata

Several small outliers of Paleozoic strata are located in the Palmerston Lake area in the northeast part of the synoptic area (Easton 1992b). All these Paleozoic units are locally derived, little transported, and probably represent the basal part of the Paleozoic sequence within the map area. They may be correlative with either the Covey Hill or Shadow Lake formations, which are generally regarded as Cambrian in age (Johnston et al. 1992).

Precambrian rocks within the eastern part of the Palmerston Lake are extremely friable and appear to have undergone extensive weathering. One explanation for this phenomenon is that the current level of exposure lies near the position of the now eroded Precambrian–Paleozoic unconformity and, locally, we see partial preservation of the pre-Paleozoic weathering surface that has been described elsewhere in southern Ontario (e.g., Di Prisco and Springer 1991).

Northwest- to West-Trending Faults

Northwest- to west-trending faults are prevalent throughout the synoptic area (*see* Map P.3443), but are best documented in the Mazinaw and Palmerston Lake areas. Both right and left-lateral faults with sizable offsets are present: 500 m along the left-lateral fault through Mazinaw Lake; 500 m along the right-lateral Plevna fault; and 500 m along the left-lateral fault running along the west shore of Mosque Lake. Although the existence of this fault set had been recognized previously (e.g., Plevna fault: Smith 1958; Pauk 1987), the abundance of faults of this trend in the area, and the scope of movement along them was previously unknown prior to detailed mapping related to this study (Easton 1994; Easton and Ford 1991; Easton 1992c, 1993).

The age of this fault set is not well constrained, but the Plevna fault offsets Paleozoic strata east of the synoptic area and has generally been regarded as part of the Ottawa–Bonnechere graben (cf. Smith 1958; Williams 1991). Metamorphic grade rises sharply across the Plevna fault, and it is likely that much of the displacement across these faults is the result of vertical, not lateral movement. Williams (1991) documents relative uplift of a few to several hundred metres across some Ottawa graben faults in the Ottawa–St. Lawrence Lowlands. Consequently, much of the west to east increase in metamorphic grade across the northern Mazinaw domain may be related to vertical movement along these faults, resulting in exposure of a deeper crustal level in northeast Mazinaw domain.

Table 6. Table of lithologic units for the Cloyne–Plevna–Ompah synoptic area.

- CENOZOIC
  - QUATERNARY
    - PLEISTOCENE AND RECENT
      - Sand, gravel, mainly glaciofluvial deposits, till, ground moraines, and organic deposits

Unconformity

- PALEOZOIC
  - MIDDLE ORDOVICIAN
    - Gull River Formation (unit 28)
      - Sublithographic to lithographic limestone, minor dolostone

Unconformity

- PRECAMBRIAN
  - NEOPROTEROZOIC
    - Grenville Diabase Dike Swarm (590 Ma) (unit 27)

Intrusive contact

- MESOPROTEROZOIC
  - Late Tectonic to Posttectonic Intrusive Rocks
    - Mafic Intrusive Rocks (<1080 Ma) (unit 26)

Intrusive contact

- Potassic Pegmatitic Intrusive Rocks (1020-1170 Ma) (unit 25)

Intrusive contact

- Felsic Intrusive Rocks, Kensington–Skootamatta Suite[c] (1050-1075 Ma) (unit 24)

Intrusive contact

Greenschist to lower amphibolite facies metamorphism in Grimsthorpe domain at ~1080 Ma
Greenschist to upper amphibolite facies in Mazinaw domain at ~1080 Ma and ~1030 Ma

- Metasedimentary Rocks of the Flinton Group (>1020 Ma, <1155 Ma)
  - Fernleigh Formation (unit 23)
    - Biotite-diopside-carbonate-hornblende schist, biotite-diopside-carbonate-hornblende schist and high grade equivalents
  - Myer Cave Formation (unit 22)
    - Black or rusty weathering, graphite-pyrite-biotite-schist; calcite marble, minor dolomite marble; carbonate clast breccia with a graphite-biotite-schist matrix; scapolite-bearing metawacke and semipelitic schist; higher grade equivalents, commonly garnet- and sillimanite-bearing
  - Bishop Corners Formation (unit 21)
    - Muscovite-rich metapelite, minor muscovite-bearing meta-arenite; metaconglomerate, dominated by clasts of metaquartzarenite; metaquartzarenite
  - Ompah Formation (unit 20)
    - Proximally derived, heterolithic metaconglomerate, consisting of granite cobbles in a carbonate-diopside-mica matrix; meta-arenite, calcareous meta-arenite; hornblende+garnet pelitic gneiss and schist
  - Norway Lake Formation (unit 19)
    - Proximally derived, heterolithic metaconglomerate, minor meta-arenite, calcareous meta-arenite

Unconformity

- Felsic Intrusive Rocks, Methuen Suite[c] (1240 to 1250 Ma) (unit 18)
  - Medium-grained, pink-weathering monzogranite, massive, foliated or gneissic, locally fluorite-bearing; locally cut by granite pegmatite veins

Intrusive contact

- Mafic to Intermediate Intrusive Rocks, Lavant Suite[c] (1240 to 1250 Ma) (unit 17)
  - Foliated to gneissic, gabbro, anorthositic gabbro, gabbroic anorthosite, foliated to gneissic, minor tonalite and granodiorite; also gneissic gabbro and diorite sills and dikes of unknown age and affinity

Intrusive contact

- Intermediate Intrusive Rocks, Elzevir Suite[c] (1250 to 1270 Ma) (unit 16)
  - Tonalite, minor granodiorite, minor diorite, massive, foliated and gneissic varieties

Intrusive contact

- Mafic Intrusive Rocks, Killer Creek Suite[c] (>1270 Ma) (unit 15)
  - Gabbro, anorthosite, anorthositic gabbro, gabbroic anorthosite, melanocratic gabbro and hornblendite, foliated to gneissic

Table 6. continued.

- PRECAMBRIAN
  - MESOPROTEROZOIC

Tectonic contact

- BLACK DONALD DOMAIN (units 10 to 14)
  - GRENVILLE SUPERGROUP
    - Metasedimentary Rocks
      - Dolomitic Carbonate Metasedimentary Rocks (unit 14)
      - Calcitic Carbonate Metasedimentary Rocks (unit 13)
      - Siliceous Clastic Metasedimentary Rocks (unit 12)
      - Siliceous Clastic Metasedimentary Rocks (unit 11)
        - Includes felsic and intermediate metatuffs and metasedimentary rocks of mainly volcanic provenance
    - Metavolcanic Rocks
      - Basalt flows; locally containing pillows, breccias and thin felsic metavolcanic units, mainly tholeiitic in composition; biotite amphibolite and minor amphibolite derived from andesite and basalt flows; locally contains pillows, breccias and thin felsic metavolcanic units, possibly calc-alkalic in composition (unit 10)

Tectonic contact

- MAZINAW DOMAIN (units 3 to 9)
  - GRENVILLE SUPERGROUP
    - Metasedimentary Rocks
      - Dolomitic Carbonate Metasedimentary Rocks (unit 9)
      - Calcitic Carbonate Metasedimentary Rocks (unit 8)
      - Siliceous Clastic Metasedimentary Rocks (unit 7)
      - Siliceous Clastic Metasedimentary Rock (unit 6)
        - Includes felsic and intermediate metatuffs and metasedimentary rocks of mainly volcanic provenance
    - Metavolcanic Rocks
      - Tholeiitic Mafic to Felsic Metavolcanic Rocks (unit 5)
        - Mazinaw Lake Formation and equivalents (1240-1250 Ma)
      - Calc-Alkalic Mafic to Felsic Metavolcanic Rocks (unit 4)
        - Kashwakamak Formation and equivalents (1265-1280 Ma)
      - Tholeiitic Mafic Metavolcanic Rocks (unit 3)
        - Tudor Formation and equivalents (>1265 Ma)
          - Also includes mafic metavolcanic rocks of unknown chemical or stratigraphic affinity

Tectonic contact

- GRIMSTHORPE DOMAIN (units 1 and 2)
  - Mafic Intrusive Rocks (unit 2)
    - Gabbro, locally foliated

Intrusive contact

- GRIMSTHORPE DOMAIN (continued)
  - Canniff Complex (>1275 Ma)
    - Tholeiitic Mafic and Felsic Metavolcanic Rocks (unit 1)

Notes: This legend is a tectonostratigraphic one, and stratigraphic order is only in part implied by numerical order. All Precambrian rocks have been subjected to regional metamorphism; many non-metamorphic terms are used for the sake of brevity and where the protolith is established. Igneous rock suites and their ages are adapted *from* Lumbers et al. (1990) and Easton (1992b). U/Pb ages are *from* Corfu and Easton (1995).

Geology

The lithology for the study area is presented in Table 6.

PRECAMBRIAN

Mesoproterozoic

GRIMSTHORPE DOMAIN

Mafic Metavolcanic Rocks (unit 1)

This unit is only represented along the shores of Pringle Lake in the southwest corner of the map area, and consist of fine-grained, dark green to black weathering amphibolite (unit 1a). These rocks are commonly fractured, cut by anastomosing, narrow (1 to 10 mm wide) quartz and plagioclase veins. In outcrop, these rocks are not fresh in appearance, and primary textures are not well preserved. These rocks most likely represent massive flows. Locally, fine-grained, dark green to black weathering, pillowed amphibolite (unit 1b) is present within the metavolcanic succession. These units are characterized by extremely thin selvages, and little hyaloclastite between the selvages.

In thin section, the mafic metavolcanic rocks are characterized by hornblende-plagioclase-actinolite assemblages with minor epidote and oxides. Plagioclase is typically oligoclase in composition. Grain boundaries are typically diffuse, with amphibole forming radiating fan-shaped aggregates, and feldspar has been uniformly recrystallized into fine-grained aggregates. This is especially evident in feldspar porphyritic rocks. Garnet is not a typical constituent of the unit 1 metavolcanic rocks. In contrast, most Tudor Formation metavolcanic rocks are characterized by fine- to medium-grained, euhedral hornblende and plagioclase.

Although it is possible that these mafic rocks in the Pringle Lake area might be better assigned to the Tudor Formation (unit 3), they are assigned to the mafic metavolcanic unit of the Canniff Complex, Grimsthorpe domain, for 2 reasons. First, like the bulk of the older mafic metavolcanic rocks present in Grimsthorpe domain, they occur in close proximity to Elzevir Suite tonalitic intrusions (Easton and Ford 1994a). Second, mafic metavolcanic rocks of the Canniff Complex appear more deformed, more altered, have less well developed primary textures, and are generally more massive than the mafic metavolcanic rocks present in Mazinaw domain.

Mafic Intrusive Rocks (unit 2)

Mafic intrusive rocks (unit 1) of the Grimsthorpe domain only occur in the southwestern part of the synoptic area. The age of these rocks is not known, however, relative age relationships outlined by Easton and Ford (1994a, 1994b) and Easton (1994) indicate that they are older than the Elzevir tonalite, which has an age circa 1270 Ma (Heaman et al. 1987).

Mafic intrusive rocks of this unit within the synoptic area are part of a large, fine-to medium-grained, gabbroic mass that intruded the Grimsthorpe Group. Contacts between the gabbros and the older supracrustal rocks are sharp, with dikes common in the vicinity of the contact. Locally, intrusion breccias are present near the contacts.

MAZINAW DOMAIN, GRENVILLE SUPERGROUP

Mazinaw Group

MAFIC METAVOLCANIC ROCKS OF THE TUDOR FORMATION (UNIT 3)

Mafic, tholeiitic metavolcanic rocks assigned to the Tudor Formation (unit 2) occur within both Grimsthorpe and Mazinaw domains. Within Mazinaw domain, they occur in the southern metaplutonic belt and the central supracrustal belt (*see* Figures 5 and 6). The thickest accumulation of these rocks occurs in the southwestern part of the synoptic area on either side of the Mooroton shear zone. In addition, mafic metavolcanic rocks of the Tudor Formation also occur as slivers between lobes of the Northbrook–Cross Lake batholith. The age of these mafic metavolcanic rocks is not precisely known. Heaman et al. (1987) assigned an age of 1279±3 Ma to rocks of the Tudor Formation, based on samples collected in western Grimsthorpe domain. This age is consistent with the data of Corfu and Easton (1995), who note that the Tudor Formation in the synoptic area is older than rocks of the overlying Kashwakamak Formation, for which they obtained an age of 1276±2 Ma. In the western Grimsthorpe domain, mafic metavolcanic rocks that have been previously assigned to the Tudor Formation (Lumbers 1967a, 1967b) are older than the 1282±3 Ma Lingham Lake intrusive complex (Easton and Kamo 2005).

Where well preserved, such as along Highway 41 south of Cloyne, the metavolcanic rocks consist of pillowed, massive and amygdaloidal flows, in which individual flows vary from 1 to 15 m thick (Photo 1). Grain size ranges from fine grained and aphyric, to fine grained and plagioclase-porphyritic, to medium grained. Pillowed flows consist of pillow forms of various sizes (from 20 to 200 cm in length) as well as pillow breccia and hyaloclastite. Pillow selvages are generally thin (<1 cm thick), and pillowed forms are commonly difficult to ascertain on lichen-covered outcrops. Because of these exposure problems, it is difficult to obtain reliable facing indicators in most outcrops; consequently, the degree of folding within rocks of unit 2 is difficult to establish. Where available, facing directions have been indicated on Map P.3443. Fine- to medium-grained sills and dikes of basaltic composition, typically 0.3 to 1 m wide, cut the flows, but are generally too small to appear on the map.

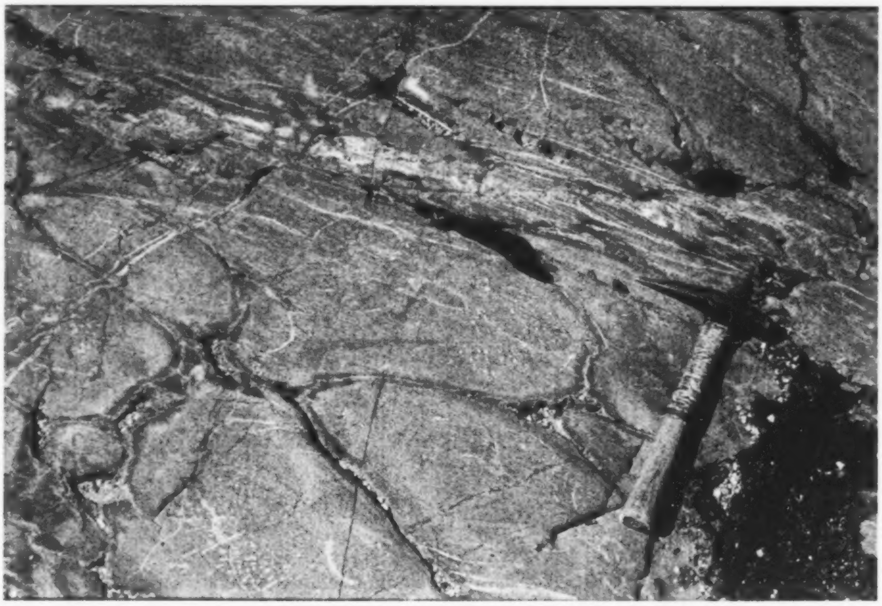

Photo 1. Well-preserved pillowed flows of the Tudor Formation, at Highway 41 and Frontenac County road 509 junction, south of Cloyne. Hammer handle is 30 cm long.

The flow rocks are dark green or green in colour, and are composed mainly of plagioclase, amphibole, epidote, chlorite and magnetite. Colour index is 40 to 50. At greenschist facies, amphibole is commonly blue-green in colour, and changes to green and then to green-brown in colour with increasing metamorphic grade. Anorthite content also increases from west to east with increasing metamorphic grade (from An_{10} to An_{55}). Pyroxene and titanite develop at higher metamorphic grades related to the breakdown of epidote. Porphyroblasts of hornblende and garnet are locally abundant at all metamorphic grades (Photo 2). Some flows are variably carbonatized, particularly in the vicinity of the Mooroton shear zone, containing brown weathering dolomite and ankerite. Where more deformed and metamorphosed, the metavolcanic rocks consist of fine-grained amphibolite and hornblende schist, and are dark green to black in colour. These rocks are aphyric or contain only small phenocrysts, generally of plagioclase. Primary depositional features are generally not preserved in the amphibolites and hornblende schists.

As Map P.3443 is in part a compilation map, mafic metavolcanic rocks that were identified in areas where mapping is of an older vintage were not accompanied by geochemical study, or are located where work was performed prior to the establishment of the multi-formation volcanic stratigraphy of Moore and Morton (1986), have been assigned to unit 3.

MAFIC, INTERMEDIATE AND FELSIC METAVOLCANIC ROCKS OF THE KASHWAKAMAK FORMATION (UNIT 4)

Mafic, intermediate and felsic metavolcanic rocks (unit 4) are restricted to the southern half of the synoptic area, and have been described in detail by Moore and Morton (1986), Harnois and Moore (1991), Sethuraman (1970), and Sethuraman and Moore (1973). The term Kashwakamak Formation was introduced by Harnois and Moore (1987, 1991) to describe metavolcanic rocks of calc-alkalic chemistry present within the Marble Lake area, and the term has been expanded in this report to include all calc-alkalic metavolcanic rocks present within the synoptic area. Uranium-lead geochronology conducted on the Kashwakamak Formation places a depositional age of 1276±2 Ma on the upper part of the formation (Corfu and Easton 1995). Volcanism was largely complete by 1267±2 Ma, the age of the tonalitic Helena stock that cuts carbonate rocks deposited contemporaneously with, or after, volcanism.

Photo 2. Hornblende-porphyroblasts present in pillowed flows of the Tudor Formation, on Highway 41, in Cloyne. Hammer handle is 30 cm long.

On Map P.3443, rocks of the Kashwakamak Formation are divided into 2 main groups: mainly mafic to intermediate rocks (units 4f, 4g, 4h, 4j) and mainly felsic rocks (units 4a, 4b, 4k). At lower metamorphic grades, both groups can be divided into flows, tuffs and pyroclastic breccias. At higher metamorphic grades, primary volcanic textures are largely obliterated, and the rocks are schistose to gneissic (units 4j, 4k).

At lower metamorphic grades, mafic to intermediate metavolcanic rocks consist of several units. The apparently lowermost stratigraphic unit consists of green-grey and grey weathering metabasalt and basaltic andesite (unit 4g), typically containing medium or coarse pseudomorphs of plagioclase phenocrysts and colour indices of 30 to 40. The transition from these rocks (unit 4g) to overlying andesitic rocks (unit 4f) is abrupt according to Moore and Morton (1986, p.8).

The andesitic rocks, at lower metamorphic grades, consist of flows, lapilli-tuff and tuff-breccia (unit 4f). The andesitic rocks are biotite rich, and have a distinctly lower colour index (20 to 30) compared to the underlying basalts and basaltic andesites of unit 4g. Lapilli-tuff and tuff-breccia are most abundant north of Big Gull Lake, and east of Pringle Lake, in the southwestern part of the synoptic area. The lapilli-tuff and tuff-breccia units consist of 20 to 70% angular to subrounded fragments, all of which have been flattened and elongated to varying degrees (Photo 3). Fragments vary from 2 mm to 1.5 m across, average size is 6 cm in tuff-breccia and 1 cm in lapilli-tuff (Moore and Morton 1986). Fragments are composed of basalt, gabbro, andesite, diorite volcaniclastic rocks and minor dacite. They are enclosed in a fine- to medium-grained matrix of sodic plagioclase, biotite, quartz and hornblende. Moore and Morton (1986) estimated that lapilli-tuff and tuff-breccia constituted 70% of the andesite succession in the Cloyne area, and that individual units ranged in thickness from 2 to 100 m. Andesite flow rocks include amygdaloidal and massive flows, with flows including autoclastic and flow breccias (Moore and Morton 1986). The andesite flows commonly contain plagioclase and hornblende phenocrysts.

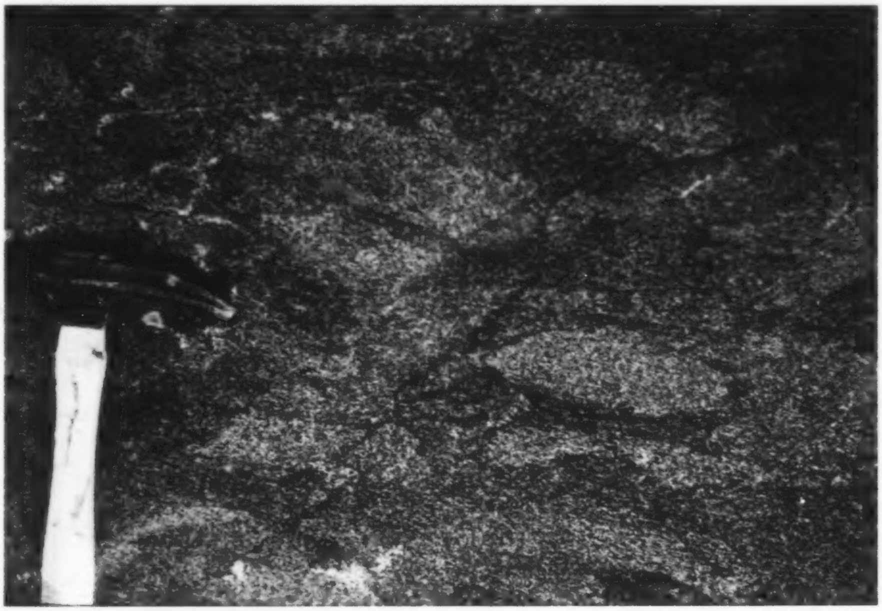

Photo 3. Monolithic tuff breccia with abundant hornblende phenocrysts, Kashwakamak Formation, south of Myer Cave (UTM Zone 18, 333172E 4964043N, NAD27). This outcrop yielded a U/Pb zircon age of 1276±2 Ma (Corfu and Easton 1995). A chemical analyses of this outcrop can be found in Appendix 1 (sample 03RME-0011). Hammer handle is 30 cm long.

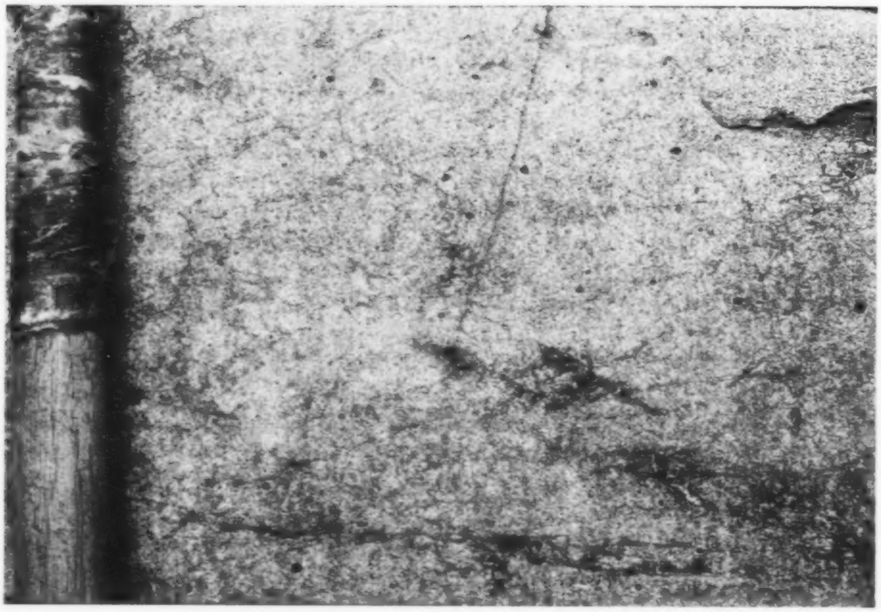

Photo 4. Magnetite porphyroblasts in grey weathering, biotite-plagioclase gneiss of the Mazinaw Lake Formation (unit 5a), on Highway 41 north of Cloyne (UTM Zone 18, 326500E 4971400N, NAD27). Compositionally, this rock is an icelandite (*see* Appendix 1, sample 91RME-0021). Hammer handle is 30 cm long.

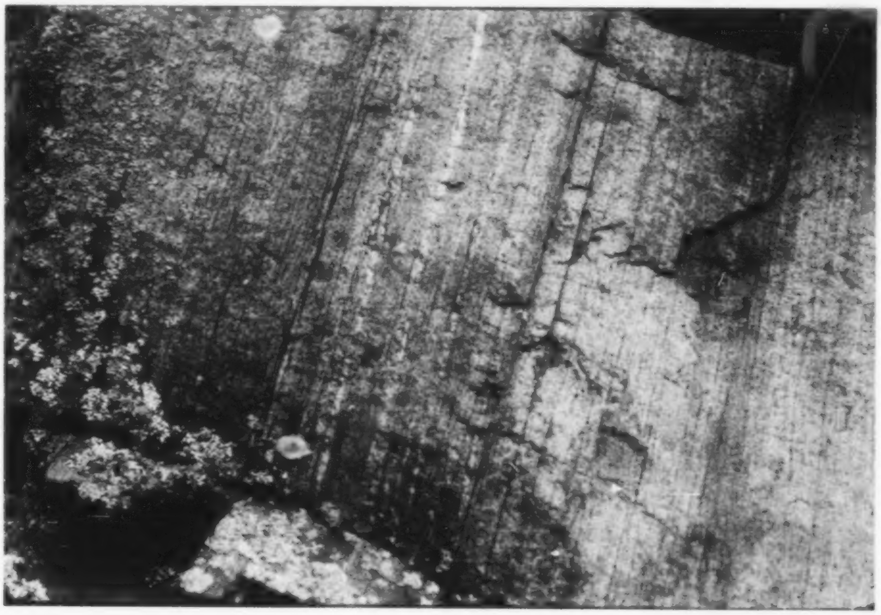

Photo 5. Gneissic, thin- to medium-layered felsite of the Mazinaw Lake Formation (unit 5b), on the south shore of Shabomeka Lake (UTM Zone 18, 332200E 4972975N, NAD27). Hornblende-porphyroblasts present in pillowed flows of the Tudor Formation, on Highway 41, in Cloyne. Hammer handle is 30 cm long.

At higher metamorphic grades, the andesitic rocks consist mainly of biotite-rich amphibolite and mafic gneiss (unit 4j) that are highly flattened and foliated.

At lower metamorphic grades, felsic metavolcanic rocks consist mainly of flows (unit 4a) and pyroclastic rocks (unit 4b) of mainly dacitic composition. Dacitic lapilli-tuff (unit 4b) and tuff-breccia are most abundant south of Kashwakamak Lake in the southwestern part of the synoptic area. They interfinger with andesitic pyroclastic rocks, are interlayered with dacite flow and volcaniclastic rocks, and are overlain by massive calcitic and dolomitic marbles (Moore and Morton 1986). The age of 1276±2 Ma for the Kashwakamak Formation reported by Corfu and Easton (1995) was from a dacitic pyroclastic flow located on the south shore of Big Gull Lake. These tuffaceous rocks vary from layered (bedded?) varieties with streaky or swirled matrices to massive units that contain a wide variety of andesitic and dacitic rock fragments.

Dacitic flow rocks (unit 4a) are relatively uncommon, are weakly layered and fine grained. Although not described by Moore and Morton (1986), south of Kashwakamak Lake, dacitic autoclastic breccias are present, consisting of blue-grey weathering, hornblende phyric, monolithic rocks, that may represent lava domes or large flow units. Corfu and Easton (1995) obtained an age of 1276±2 Ma for one of these dacitic autoclastic breccias.

At higher metamorphic grades, the dacitic rocks consist mainly of biotite-rich quartzofeldspathic schist and gneiss (unit 4k) that are highly flattened and foliated.

Moore and Morton (1986) suggested that, within the Marble Lake area, the main volcanic centre for the Kashwakamak Formation was located just south of the synoptic area, between Harlowe and Kashwakamak Lake. The location of the volcanic centre was inferred from the presence of numerous subvolcanic intrusive rocks, swarms of dacitic dikes, and abundance of pyroclastic rocks, especially tuff-breccias, and evidence of hydrothermal activity in and adjacent to the subvolcanic intrusions. Using similar criteria, a second volcanic centre is located adjacent to northeast corner of the synoptic area, centred around LaFrance Lake in the Dalhousie Lake area (Pauk 1989a). This volcanic centre is the likely source for much of the Ompah Formation present in the northeast corner of the synoptic area.

MAFIC AND FELSIC METAVOLCANIC ROCKS OF THE MAZINAW LAKE FORMATION (UNIT 5)

Mafic and felsic metavolcanic rocks (unit 5) of the Mazinaw Lake Formation occur in the central part of the synoptic area, and have been described in detail by Ayer (1979), who first introduced the term Mazinaw Lake Formation for mafic and felsic tholeiitic metavolcanic rocks located between Pringle and Shabomeka Lake. Ayer (1979) thought that they were older than the calc-alkalic metavolcanic rocks of the Kashwakamak Formation, based in part on the tholeiitic character of the metavolcanic rocks (*see* Figure 7). Subsequent U/Pb geochronology by Corfu and Easton (1995) established that metavolcanic rocks of the Mazinaw Lake Formation were emplaced at circa 1245 Ma, some 25 to 30 million years after deposition of the Kashwakamak Formation.

Two main compositional groups are present within the Mazinaw Lake Formation, basaltic andesites of tholeiitic composition known as icelandites (unit 5b) and rhyolitic, tholeiitic, metavolcanic and subvolcanic intrusive rocks (units 5a, 5c). The felsic rocks tend to be fine grained, and of low colour index (10 or less) and, with increasing deformation, are best described as felsites.

Four main rock types are distinguished within the Mazinaw Lake Formation.

1. finely laminated, pink, buff, or grey weathering, quartzofeldspathic gneisses ("felsites"), locally containing garnet, plagioclase or magnetite porphyroclasts (unit 5a) (Photo 4).
2. foliated, grey weathering, hornblende-biotite-plagioclase gneisses that contain randomly oriented garnet ± magnetite ± hornblende porphyroblasts (unit 5b) (Photo 5).

3. finely laminated, pink, buff, or grey weathering, quartzofeldspathic gneisses containing fragmental textures, likely representing pyroclastic deposits, including ash and crystal tuffs (unit 5c).
4. finely laminated, green to dark green biotite-hornblende-plagioclase mafic gneisses (unit 5d). The mafic gneisses are commonly intercalated on a 5 to 30 m scale with the quartzofeldspathic gneisses.

In the Pringle Lake area, due south of Bon Echo Park, and along highway 41, 1.5 km south of the southern park boundary, is a unit of distinctive, grey to dark grey, massive, biotite-hornblende-quartz-plagioclase gneiss, commonly containing euhedral magnetite, and locally garnet, porphyroblasts (unit 5b). No primary textures are preserved in this unit, and it is unclear if the unit is bedded. If bedded, bedding is on the scale of 3 to 10 m. This unit probably represents a massive basaltic andesite flow unit (icelandite), or a metawacke of volcanic provenance. Unit 5b has a colour index of 15 to 25, and consists of albite, quartz, microcline, biotite and hornblende. Accessory minerals include magnetite, titanite, carbonate, and apatite. Ayer (1979) reports rare garnet and fluorite in this unit. Average matrix grain size is 0.4 mm.

Ayer (1979) and Moore and Morton (1986) inferred the presence of a volcanic centre for the Mazinaw Lake Formation in the area between Pringle and southern Mazinaw Lake, based on the presence of numerous subvolcanic intrusive rocks, swarms of felsic dikes, and the abundance of coarse pyroclastic rocks. As shown in Figure 5, 2 other volcanic centres within the Mazinaw Lake Formation are inferred to occur in or adjacent to the synoptic area. Near Plevna, the presence of a major volcanic centre is inferred. This centre is complexly folded around the Plevna syncline, and the rocks that constitute the volcanic centre are highly deformed and not well exposed. Volcaniclastic (unit 6) and siliciclastic (unit 7) metasedimentary rocks present to the west, south and east of this volcanic centre are inferred to be turbidite fan systems that developed in response to input of clastic debris that was eroded from this centre (be it wholly submerged or partly emergent). An abundance of dolomitic marbles is also present in the vicinity of this centre, and the deposition of these rocks may also be directly related to this volcanic centre (*see* Figure 5). A third volcanic centre is also thought to have been present near Flower Station in the Darling area (Easton 1988), northeast of the synoptic area. Siliciclastic metasedimentary rocks (units 6 and 7) present near Ompah in the Palmerston Lake area, are thought to represent clastic detritus transported southward from the volcanic centre located near Flower Station (*see* Figure 5).

VOLCANICLASTIC ROCKS (UNIT 6)

This unit comprises rocks that are not clearly volcanic or sedimentary in origin that are found in the central supracrustal and northern metaplutonic belts of Mazinaw domain. The unit probably includes primarily deposited volcanic sediments, as well as epiclastic rocks containing a high proportion of volcanic detritus. Throughout most of the synoptic area, these rocks are preserved at amphibolite facies, making protolith identification difficult. In the older literature, many mafic rocks present in this unit were termed "para-amphibolite", and consist of fine- to medium-grained, dark green to grey-green weathering, biotite-hornblende-plagioclase schists or gneisses of indeterminate protolith. Moore and Morton (1986) report the presence of bedded to massive basaltic volcanic sandstones within the Marble Lake area, and it is possible that such rocks may be the protolith to many of the rocks that constitute unit 6. It is also likely that the unit includes intercalated mafic and felsic metavolcanic rocks, which were highly sheared and deformed, and which were subsequently recrystallized during M_2 regional metamorphism to form some of the rocks that constitute this unit.

Mineralogically rocks of this unit are dominated by plagioclase and hornblende. Common accessory minerals are garnet, biotite, scapolite and carbonate.

Five subunits are distinguished on Map P.3443, as follows:

1. unit 6a consists of biotite-hornblende-quartz-plagioclase gneiss ("para-amphibolite") and hornblende-plagioclase gneiss, with layers of unit 4 or 5 present locally.
2. unit 6b consists of thinly layered, fine-grained, silicified quartzofeldspathic gneisses, possibly representing altered mylonitized sedimentary rocks.
3. unit 6c consists of calcareous, flattened and sheared biotite-hornblende-carbonate-diopside gneiss and schist ("para-amphibolite"), biotite-plagioclase-quartz and carbonate-scapolite-quartz gneiss.
4. unit 6d consists of biotite-hornblende-quartz-plagioclase gneiss ("para-amphibolite"), hornblende-plagioclase gneiss, and quartzofeldspathic gneiss, commonly garnet bearing, may include layers of unit 3 or 5.
5. unit 6e consists of biotite-hornblende-quartz-plagioclase schist to gneiss, derived from volcanic wackes and volcanic arenite.

For the most part, rocks of unit 6 are distinguished from mafic metavolcanic rocks of units 3 and 4 by the presence of biotite, the lack of obvious volcanic textures, and a high degree of recrystallization.

Unit 6c differs from the other subunits in having a higher carbonate content, and is locally interlayered with calcitic marbles (units 8a and 8b). Two types are present. The first occurs in the higher grade parts of the synoptic area, where intermediate to felsic composition volcanic or volcaniclastic rocks that are characterized by the presence of large calcite-hornblende-diopside clots within layered, grey-green weathering gneiss are common (Photo 6). Easton (1988) reported similar rocks from the adjacent Darling map area immediately northeast of the synoptic area. These intermediate to felsic gneisses can form from rocks of either the Kashwakamak and Mazinaw Lake formations, and appear to result from

Photo 6. Calc-silicate clots (calcite-hornblende-diopside) in grey-green weathering, layered, dacitic composition gneiss, Sunday Lake area. These intermediate to felsic composition volcanic or volcaniclastic rocks are common in the higher grade portions of the Kashwakamak and Mazinaw Lake formations, and appear to result from metamorphism of volcanic rocks rich in carbonate material. Hammer handle is 30 cm long.

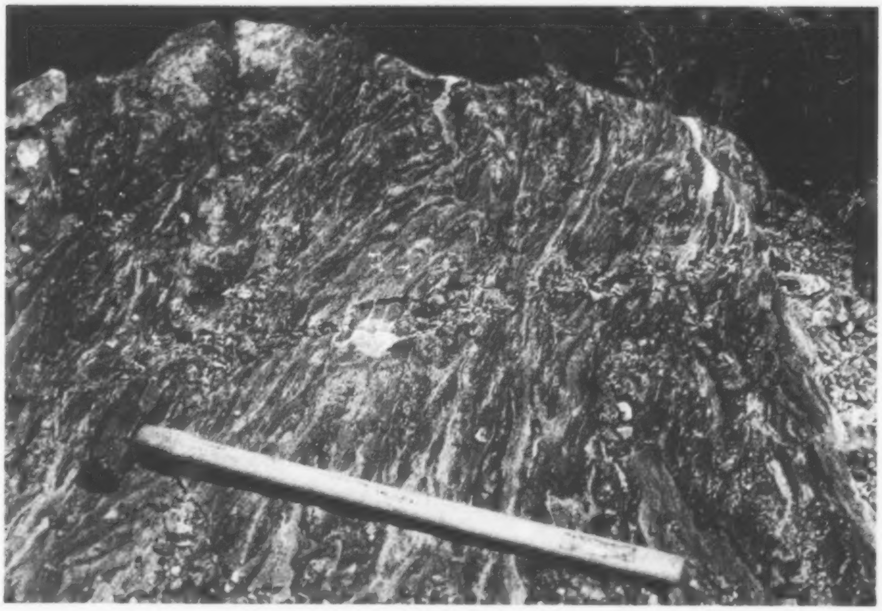

Photo 7. Thin-layered, dolomite-amphibolite rock (unit 6c) south of Ardoch (UTM Zone 18, 350141E 4976300N, NAD27). Dolomite layers are recessive weathering. Rock could represent either a succession of mafic tuffs interbedded with carbonate layers, a peperite formed by the mixing of volcanic flows or sills with carbonate sediments, or tectonism of a highly carbonatized mafic volcanic rock. Hammer handle is 50 cm long.

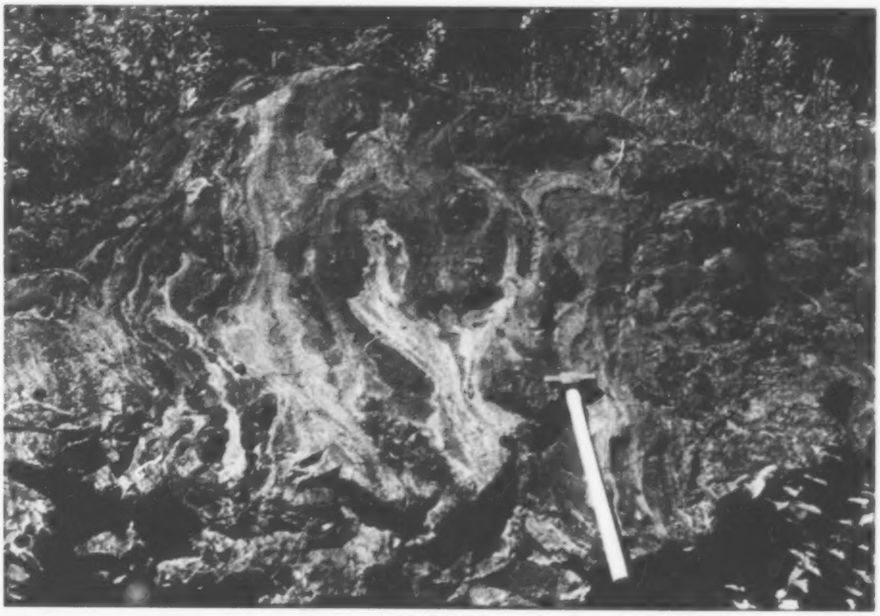

Photo 8. Highly contorted, thin-layered, dolomite-amphibolite rock (unit 6c) south of Ardoch (UTM Zone 18, 350063E 4976482N, NAD27). Dolomite layers are recessive weathering, but are more abundant than in Photo 7. Hammer handle is 50 cm long.

metamorphism of volcanic rocks rich in carbonate material. The second type occurs mainly in a linear belt on the south side of the Fernleigh belt, south and east of Ardoch. On outcrop surfaces, these rocks are commonly brown to chocolate-brown weathering, with randomly oriented, elongate blades of hornblende, up to 1.5 cm long, present on foliation surfaces (Photos 7 and 8). Apart from the hornblende blades, the rock itself is fine grained, and is well foliated to schistose. Foliation is defined by alternating bands of biotite-plagioclase-quartz, biotite, and carbonate-scapolite-quartz that alternate with layers of hornblende-carbonate-diopside schist, containing the mineral assemblage hornblende-carbonate-diopside-scapolite-oligioclase-quartz ± biotite ± garnet. Pauk (1987) also reported the presence of relict grains of staurolite and garnet poikiloblasts in the biotite-rich bands.

The origin of unit 6c is problematic. Pauk (1987) interpreted these rocks as a pile of mafic volcanic ash and volcaniclastic sediment that was deposited concurrently with the carbonate sediments. The possibility of a tectonic origin for these rocks cannot be excluded. The author has observed similar rocks in southern Mazinaw domain and, invariably, they occur in high-strain zones found to the east of belts of Flinton Group rocks, or along domain boundaries. In the synoptic area, the character of the southern contact of the Fernleigh belt is not well understood, but its linear nature could be the result of a tectonic (faulted) origin. Thus, although Pauk (1987) may be correct that the primary origin of these rocks is due to concurrent sedimentation of mafic tuffs and carbonate sediments, the fine-scale interlayering of carbonate and mafic material now observed in these rocks, may be the result of extreme deformation, and subsequent metamorphism, of this volcanic-carbonate protolith.

CLASTIC METASEDIMENTARY ROCKS (UNIT 7)

This unit comprises a variety of quartzofeldspathic rocks present within the central supracrustal belt of Mazinaw domain. Three main varieties are present, which probably represent metamorphosed greywackes, sandstones and siltstones, respectively.

The bulk of the siliciclastic metasedimentary rocks of unit 7 occur within the rifted-arc succesion of the central supracrustal belt of Mazinaw domain. Metamorphosed greywackes are best preserved west and northwest of Plevna Lake, and consist of medium-grained, grey weathering, medium- to thick-bedded wackes (turbidites) that probably contain a high percentage of volcanic detritus (Photo 9). These rocks are similar to volcaniclastic wackes present within the Apsley Formation of the Belmont domain, which have been described in detail by Easton (1986b). Bedding in the metawackes ranges from sharp to indistinct (*see* Photo 9). Bouma sequences are locally observed, but most beds exhibit only B–C forms, suggestive of mid-fan environments in turbidite fan systems, not the distal fan regimes that produce more typical Bouma sequences (Walker 1984).

Dark grey weathering metawacke and volcaniclastic metasedimentary rocks (unit 6) along Swamp Creek that extend as far east as Little Green Lake, grade westward into dark grey, grey and green-grey weathering, metawacke and biotite-epidote metawacke (unit 7) exposed east of Mississagagon Lake. This facies change appears to represent increased reworking of the volcanic detritus with increasing distance away from the Plevna volcanic centre. This belt of siliciclastic and volcaniclastic metasedimentary rocks is closely associated with a large area of medium-grained, blue-grey weathering dolomite marbles (unit 9) located east-southeast of Plevna. All the siliciclastic, volcaniclastic, and dolomitic metasedimentary rocks described in this paragraph are all proximal to the Mazinaw Lake Formation volcanic centre inferred to be present east of Plevna (*see* Figure 5).

This association of sedimentary and volcanic rock types has been observed near other volcanic centres within the Central Metasedimentary Belt (e.g., Easton 1992b). Easton (1992b) suggested that Central Metasedimentary Belt volcanic centres were submergent to locally emergent in a marine setting, and that such centres were surrounded by aprons of siliciclastic and metasedimentary rocks and that,

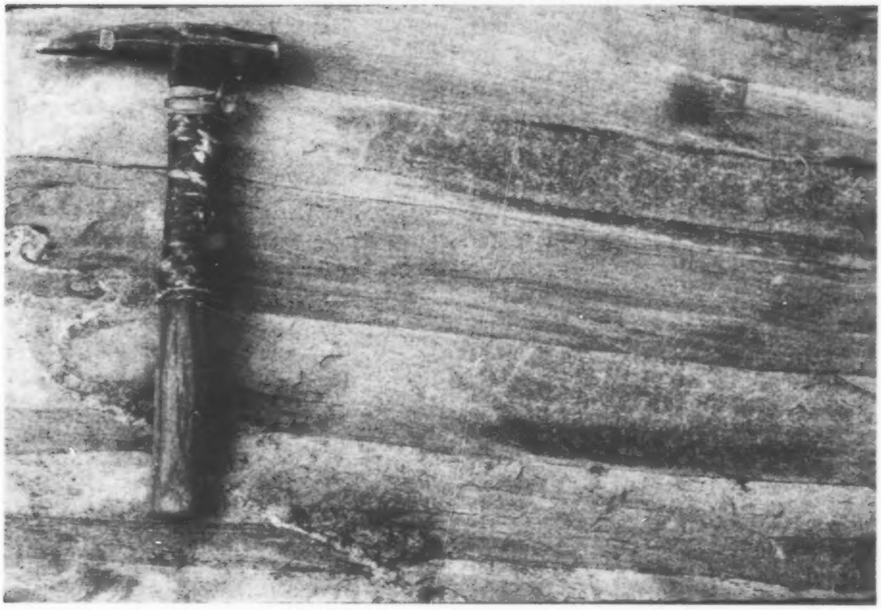

Photo 9. Medium-layered turbidites (unit 7) of the Mississagagon Formation, west of Plevna (UTM Zone 18, 338830E, 4979140N, NAD27). An analysis of this unit is provided in Appendix 1 (sample 91RME-0050). Hammer handle is 30 cm long.

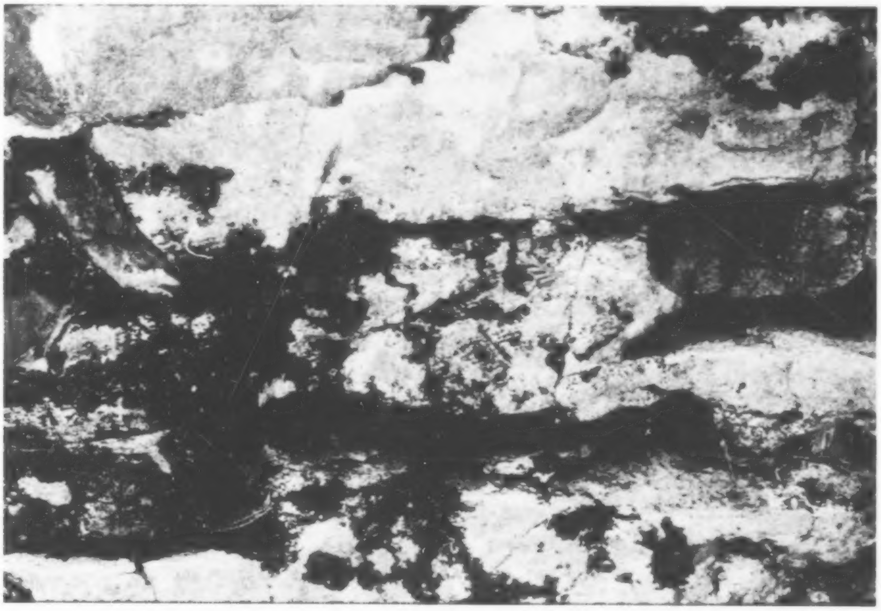

Photo 10. Algal-mat stromatolites present in thin-layered, siliceous, dolomite marble at Sunday Lake (UTM Zone 18, 360050E, 4987900N, NAD27).

during the waning stages of volcanism and sedimentation, carbonate platforms, dominated by dolomite marble, commonly stromatolitic, formed in shallow waters on the flanks of these volcanic centres. Areas between the volcanic centres consist mainly of calcitic marbles.

CALCITE MARBLE: MAZINAW DOMAIN (UNIT 8)

Calcite marble, generally medium to coarse grained and massive, locally layered, medium-grained calcite marble (unit 8a), may include zones with intact or boudinaged layers of siliceous clastic metasedimentary rocks (unit 6 and 7). South of Ardoch, calcite marbles that are interlayered with para-amphibolite of unit 6d are identified as unit 8b on Map P.3443.

DOLOMITE MARBLE: MAZINAW DOMAIN (UNIT 9)

Dolomite marble within the map area is generally medium to coarse grained and massive (unit 9a), but locally may include zones of calc-silicate assemblages (e.g. tremolite, diopside). Areas of dolomitic marble containing significant interlayers of siliceous clastic metasedimentary rocks (unit 9b) occur primarily in the southwestern part of the synoptic area, in association with the Harlowe volcanic centre.

Dolomite marbles appear to be more abundant within the rifted-arc succession of Mazinaw domain. These dolomite marbles are generally found proximal to the volcanic centres identified within the Mazinaw Lake Formation (*see* Figure 5), and it is possible that many of the dolomite marbles present within the rifted-arc succession were deposited in shallow waters associated with these centres. Dolomite marble in the rifted-arc succession commonly contains quartz segregations, some of which contain the fine laminations typical of algal-mat stromatolites (Photo 10). Stromatolitic-marbles are observed on the north and eastern shores of Marble Lake. In addition, a belt of dolomite marble containing quartz segregations can be traced discontinuously along strike from Palmerston Lake to Lavant Long Lake, and several possible stromatolite occurrences were noted along this belt by Easton, Ford and Cooke (1995). Dolomite marble containing quartz segregations, that may be relict algal-mat stromatolites, are also observed on the north shore of Sunday Lake.

GRENVILLE SUPERGROUP: BLACK DONALD DOMAIN

Grenville Supergroup rocks within the Black Donald domain, located in the northwest part of the synoptic area, are, in many respects, similar lithologically to the Grenville Supergroup rocks of Mazinaw domain and, ultimately, may be shown to be correlative with them. The synoptic map (*see* Map P.3443) is a tectonostratigraphic map; however, it was determined that it was best to treat the major rock units within the Black Donald domain as separate formations within the Grenville Supergroup.

Mafic Metavolcanic Rocks (unit 10)

Mafic metavolcanic rocks of unit 10 are located mainly in the Wensley area, near the Mazinaw–Black Donald domain boundary. All are at amphibolite facies, shown varied degrees of strain, and rarely show any primary volcanic or igneous textures.

Two varieties are shown on the synoptic map, based largely on the subdivision of Lumbers and Vertolli (2001). Unit 10a consists of green and dark green weathering, fine- to medium-grained amphibolite and mafic gneiss, thought to be derived from flows of basaltic composition. Medium-grained rocks of unit 10a may represent coarse flows or subvolcanic sills. According to Lumbers and Vertolli (2001), these rocks are tholeiitic in chemistry, and are considered by them to be equivalents of the Tudor

Formation. Unit 10b consists of green and grey-green weathering, fine- to medium-grained amphibolite and mafic gneiss, thought to be derived from flows of basaltic and andesite composition, but containing biotite, and apparently exhibiting calc-alkalic chemistry (Lumbers and Vertolli 2001). The latter could be a primary chemical signature, or it could be due to the alteration of the original rocks (for instance, due to addition of carbonate). Metavolcanic rocks of unit 10 were not sampled for chemistry as part of this study; consequently, it is not known for certain if the chemical differences reported by Lumbers and Vertolli (2001) are indeed magmatic in origin, or whether the presence of biotite in rocks of unit 10b is the result of hydrothermal alteration or some other alteration process.

Volcaniclastic Rocks (unit 11)

Volcaniclastic rocks of unit 11 comprise mafic rocks that are not clearly volcanic or sedimentary in origin and are very similar in appearance to the volcaniclastic rocks of unit 6. Within the Black Donald domain, rock of unit 11 occur in close proximity to the mafic metavolcanic rocks of unit 10, but are also intercalated with calcite and dolomite marbles of units 12 and 13, respectively. Referred to as "para-amphibolite" in the older literature, rocks present in this unit are preserved only at amphibolite facies, making protolith identification difficult. They consist of fine- to medium-grained, dark green to grey-green weathering, biotite-hornblende-plagioclase schists or gneisses of indeterminate protolith. Carbonate-, scapolite- and titanite-bearing varieties are also present, especially in proximity to carbonate metasedimentary rocks of unit 12 and 13, and some of the para-amphibolites may originally have been calc-silicate rocks.

Due to the high metamorphic grade and difficulty in recognizing protolith, it is also likely that this unit of mafic volcaniclastic rocks includes several types of sheared and deformed rocks that were subsequently recrystallized during regional metamorphism to form mafic gneiss and para-amphibolite. In addition to including deformed mafic and felsic metavolcanic rocks, mafic volcaniclastic rocks of unit 10 typically mantle 2 large Lavant suite gabbro intrusions (unit 17) in the domain, and it is likely that the mafic volcaniclastic unit includes deformed gabbros derived from these intrusions.

Clastic Metasedimentary Rocks (unit 12)

Clastic metasedimentary rocks of unit 12 are typically found intercalated with carbonate metasedimentary rocks within the Black Donald domain. Sand-size material is uncommon within these siliciclastic rocks; more typically, they are calcareous or micaceous in composition, and were likely derived from metamorphism of siltstone and mudstone, including calcareous siltstones. They are buff to grey-weathering, and commonly slightly rusty weathering. Where proximal to metavolcanic and metavolcaniclastic, dark-weathering, rusty-weathering pyritic schists layers are common within this unit.

Calcite Marble (unit 13)

The most abundant supracrustal rock type within the Black Donald domain consists of layered to bedded, medium-grained, grey to white-grey weathering, calcite marble (unit 13), locally cut by white tonalite and pink granite veins. Although the marbles are locally interlayered with amphibolite, likely representing mafic metavolcanic flows and tuffs (unit 10), and volcanic-derived metasedimentary rocks (unit 11), the marbles are generally fairly clean, generally only containing minor amounts of chondrodite or phlogopite as accessory minerals. This is especially the case in the Fortune and Round Schooner Lake areas, where the lack of impurities and high brightness of some of the calcite marbles warrants further examination for their industrial mineral potential. Marble tectonic breccia occurs locally within this unit, but is not abundant enough to be portrayed on Map P.3443.

Two subunits are shown on Map P.3443, based on mapping by Lumbers and Vertolli (2001). Unit 13a consists of medium- to coarse-grained and massive calcite marble, which may locally contain zones with intact or boudinaged layers of siliceous clastic metasedimentary rocks (unit 11 and 12). Unit 13b contains more siliceous impurities (20 to 60%), as well as thin intercalated layers of unit 12. Unit 13b includes rocks that can be termed marble tectonic breccias.

Unlike the calcite marbles in the Mazinaw domain, those in Black Donald domain show a closer association with, and significant interlayering with, the volcaniclastic (unit 11) and clastic metasedimentary (unit 12) rocks of the domain. In Mazinaw domain, the calcite marbles are more distal to, and perhaps younger than, the volcaniclastic, clastic and dolomite sediment aprons that develop around the various volcanic centres present in the domain. In Black Donald domain, we may be more proximal to the source region(s) of the sedimentary rocks, and consequently, we are seeing repeated influxes of clastic material in a carbonate basin, resulting in greater interfingering of clastic (units 11 and 12) and carbonate (unit 13 and 14) rocks.

Dolomite Marble (unit 14)

Dolomite marble of unit 14 typically occurs as thin (<100 m thick) intercalated horizons within the calcite marbles (unit 13) of the Black Donald domain. The dolomite marble is generally massive, blue-grey or buff weathering; locally layering is present. Like the calcite marble, the dolomite marble is locally cut by white tonalite and pink granite veins. Two subunits are shown on Map P.3443, based on mapping by Lumbers and Vertolli (2001). Unit 14a consists of medium- to coarse-grained and massive, dolomite marble, with zones of calc-silicate assemblages (e.g. tremolite, diopside), and minor interlayered siliceous clastic metasedimentary rocks (unit 12). Unit 14b contains more siliceous impurities (up to 20%), and intercalated layers of tremolite-rich dolomitic marble. Unit 14b may host relict algal-mat stromatolites.

Unlike the dolomite marbles in the Mazinaw domain, those in Black Donald domain do not show a consistent association with any particular rock units, nor do their geographic distribution show a clear association with either the metavolcanic or metavolcaniclastic rocks in the domain. As such, the depositional environment of the dolomite marbles in Black Donald domain is problematical.

INTRUSIVE SUITES

Mafic Intrusive Rocks, Killer Creek Suite (unit 15)

Defined by Easton (1992b), the Killer Creek Suite consists of gabbro to leucogabbro intrusions that were emplaced prior to the circa 1270 million-year-old Elzevir Suite. The intrusions of this suite are best preserved in Grimsthorpe domain, but they do occur sporadically throughout Mazinaw domain, particularly in the region north of the Shabomeka shear zone (*see* Map P.3443). In addition to gabbro and leucogabbro phases, intrusions of the Killer Creek Suite locally contain hornblendite and anorthosite. Lumbers et al. (1990) do not have a direct equivalent of the Killer Creek Suite in their classification of Central Metasedimentary Belt magmatic suites, but some intrusions of the Killer Creek Suite are included by Lumbers et al. (1990) in their "Anorthosite Suite" section.

Composition of the Killer Creek Suite ranges from ultramafic to anorthositic; locally, some of these rocks preserve igneous layering. The most abundant rock type consists of holocrystalline, medium-grained, hornblende gabbro with a colour index of 35 to 40 (unit 15a). Other varieties include medium-grained melanocratic gabbro (colour index 40 to 60, unit 15c), generally found in association with hornblendite pods. Within Bon Echo Provincial Park, altered and recrystallized equivalents of unit 15c form fine-grained, chlorite-magnetite schists (unit 15d). Anorthositic gabbros, gabbroic anorthosite and anorthosite (unit 15b) are also common, and may locally preserve igneous layering. Rocks of the Killer Creek Suite are best preserved in the southwest part of the synoptic area; with deformation and metamorphic recrystallization increasing to the northeast, to the extent that rocks of unit 15 in the northeast part of the synoptic area are gneissic (unit 15g). Mylonitized equivalents of rocks of the Killer Creek Suite (unit 15h) are found in the domain boundary separating Grimsthorpe and Mazinaw domains.

Unlike Grimsthorpe domain to the west, no large, discrete intrusions of Killer Creek Suite rocks occur in Mazinaw domain. Rather, rocks of this suite crop out in a discontinuous belt along the southern margin of the Abinger Granite, from the southern end of Mazinaw Lake to the northeast corner of the synoptic area (*see* Map P.3443). Rocks of unit 15 are spatially associated with tonalitic gneisses of the Elzevir Suite (unit 16) and, locally, both units can contain inclusions of amphibolitic material of unknown origin. This belt of the Killer Creek and Elzevir suite rocks has been interpreted by the author as a possible basement complex to the Mazinaw Lake Formation and the Abinger and Norway Lake complexes, as discussed in "Regional Geological Setting", "Mazinaw Domain", "Overview", and as illustrated in Figure 5. This basement complex was probably originally much like the eastern part of Grimsthorpe domain, and likely formed at circa 1270 Ma. Eruption and injection of the Mazinaw Lake Formation and the Methuen Suite granitic rocks then occurred at circa 1250 Ma.

Intermediate to Felsic Intrusive Rocks, Elzevir Suite (unit 16)

Defined by Easton (1992b), and modified by Praamsma, Wodicka and Easton (2000), the Elzevir Suite is among the most voluminous magmatic suite present within the Central Metasedimentary Belt. The suite consists of several rock types, including trondhjemite, tonalite and granodiorite. Albite granite and alkali feldspar granite occur as late dikes cutting plutons of the suite. Most of the tonalite and trondhjemite bodies are of the high-alumina type, and are biotite rich. Chemically, they fall between calc-alkalic and trondhjemite trends. Lumbers et al. (1990) report U/Pb zircon ages of 1280 to 1270 Ma for rocks of the Elzevir Suite located in Grimsthorpe and Belmont domains, and Praamsma, Wodicka and Easton (2000) report a similar age range from the Pakenham area of Sharbot Lake domain. Corfu and Easton (1995) reported a U/Pb zircon age of $1250^{+10}/_{-15}$ Ma for the Northbrook pluton within Mazinaw domain, suggesting that rocks of the Elzevir Suite may have been emplaced over a 30 million-year time frame. An origin by partial melting of tholeiitic basalts in either an island-arc or mantle-activated rift is suggested by Lumbers et al. (1990) for rocks of the Elzevir Suite.

The most common rock type of this suite consists of grey weathering, grey, medium-grained tonalite and minor granodiorite (unit 16d), which becomes more foliated to gneissic (unit 16n) toward the northern and northeastern parts of the synoptic area (Photos 11 and 12). Crosscutting granite pegmatite veins, both deformed (Photo 13) and undeformed, are also common in unit 16 rocks in the higher grade parts of the synoptic area. In Bon Echo Provincial Park, intrusion breccias consisting of either blocks of unit 15, or units 1 and 2, in a tonalitic matrix, are common (Photo 14) (Easton 1994; Easton et al. 1994, 2001).

Within Mazinaw domain, rocks of the Elzevir Suite form 3 main intrusions. The largest and most continuous is the Northbrook–Cross Lake intrusion, which occurs in the southeastern part of the synoptic area. This body has been dated at $1250^{+10}/_{-15}$ Ma (Corfu and Easton 1995). The second largest body occurs in the northwest part of the synoptic area, and is part of the Weslemkoon intrusion, which has been dated at circa 1270 Ma (Lumbers et al. 1990). The third largest body occurs in the Big Lake–Reid Lake area in the northeastern part of the synoptic area, and may represent part of the basement complex that extends from Mazinaw Lake to the northeast corner of the synoptic area. Isolated slivers of tonalitic rocks of the Elzevir Suite occur within, and along the southern margin of the Abinger Granite.

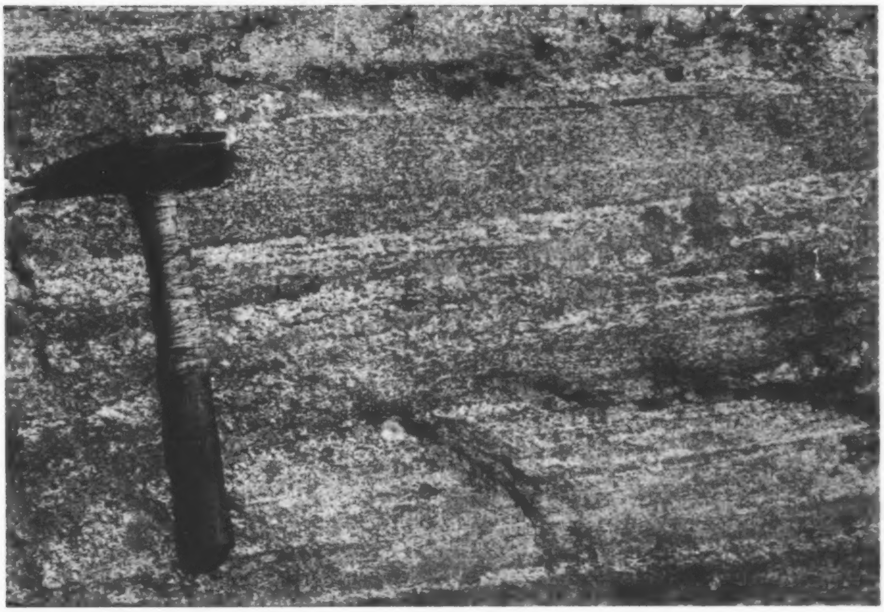

Photo 11. Tonalite gneiss (unit 16n), from the northwest part of the synoptic area (UTM Zone 18, 353760E 4992720N, NAD27). Note 2 generations of leucosome: the earlier leucosome layers are parallel to the foliation in the rock, whereas the younger layers are slightly discordant to the foliation. Hammer handle is 30 cm long.

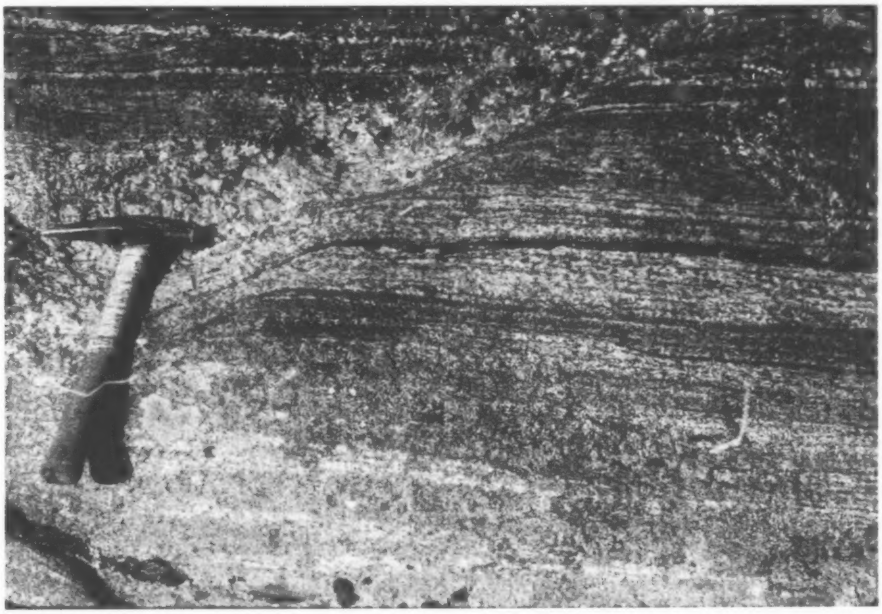

Photo 12. Tonalite gneiss (unit 16n), from the northwest part of the synoptic area (UTM Zone 18, 353760E 4992720N, NAD27). Note crosscutting, undeformed, granite pegmatite vein in upper left hand portion of the photograph. Hammer handle is 30 cm long.

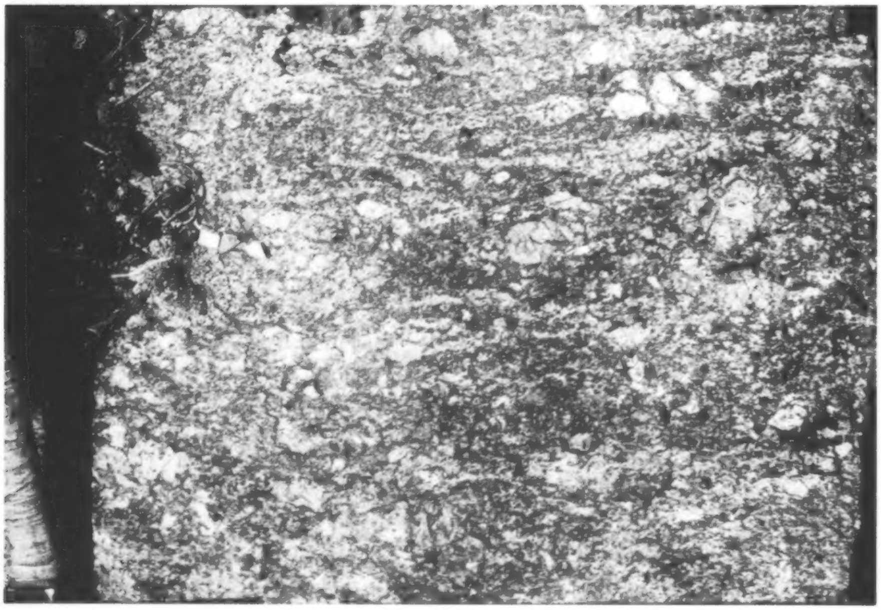

Photo 13. Porphyroclastic granite pegmatite vein, hosted by tonalite gneiss (unit 16n) shown in Photo 12, from the northwest part of the synoptic area (UTM Zone 18, 353990E 4993040N, NAD27). Zircon from this dike yielded an age of 1063±5Ma, whereas zircon from an undeformed granite pegmatite vein cutting the deformed vein gave a U/Pb age of 1079±2 Ma (Corfu and Easton 1995). The older age for the undeformed pegmatite could reflect a minor inherited component. Hammer handle is 30 cm long.

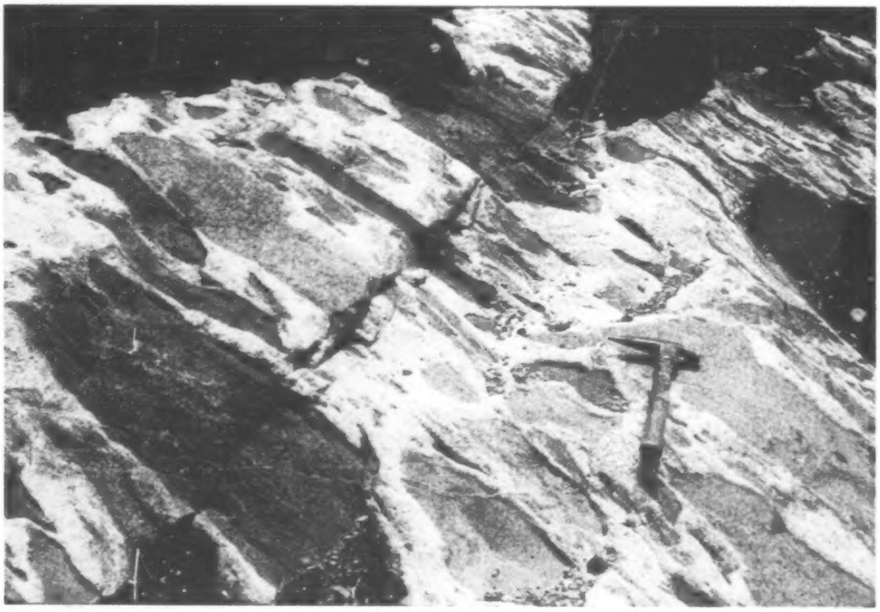

Photo 14. Intrusion breccia on Highway 41, with fragments of amphibolite, gabbro and diorite in slightly pinkish weathering granodiorite matrix (UTM Zone 18, 325830E 4972490N, NAD27). Hammer handle is 30 cm long.

Within Black Donald domain, rocks of the Elzevir Suite are also present, but do not form discrete plutonic bodies, rather they occur as more lenticular masses of well-foliated to gneissic rock interlayered with clastic and carbonate metasedimentary rocks. Another difference from Mazinaw domain is that rocks of the Elzevir Suite in Black Donald domain do not occur in close association with amphibolites (mafic metavolcanic rocks), gabbroic and anorthositic gabbroic rocks (Killer Creek Suite), or granitic rocks of Methuen Suite (unit 18). There are several different explanations for this difference in map pattern between the two domains. First, it could be due to injection of tonalitic to granodioritic magmas into the sedimentary sequence prior to, or during, regional metamorphism. Second, it could result from deposition of the sedimentary rocks on a tonalitic basement complex, which has then been intensely folded by at least 2 generations of folds. Third, it could be due to tectonic interleaving of metasedimentary and metaplutonic rocks. Most likely, it is the result of the combination of several of these different processes.

Mafic Intrusive Rocks, Lavant Suite (unit 17)

Mafic intrusive rocks of the Lavant Suite (Easton 1992b), also termed the "Diorite Suite" by Lumbers et al. (1990), are poorly represented in Mazinaw domain within the synoptic area, and consist of a single stock located south of Plevna, and a few small intrusions present northeastern of Palmerston Lake. An equal or slightly larger volume of Lavant Suite mafic intrusions occurs within the Black Donald domain in the northwestern part of the synoptic area. Rocks of this suite are undated within Mazinaw domain, but elsewhere in the Central Metasedimentary Belt, yield U/Pb zircon ages of 1245 to 1240 and circa 1225 Ma (Davis and Bartlett 1988; Corfu and Easton 1997). The restriction of Lavant Suite intrusions to the rifted-arc succession within Mazinaw domain, and their spatial association with Methuen Suite granitic rocks, suggests that they are likely approximately 1245 million years old.

The stock south of Plevna lies in the core of the Plevna synform, and is heterogeneous in composition, ranging from gabbro to granodiorite. It consists mainly of medium-grained, gabbroic and diabasic textured gabbro, generally exhibiting a weakly developed fabric. In thin section, the gabbro consists of large, anhedral grains of hornblende and plagioclase. In many samples, fine-grained granoblastic plagioclase has completely replaced small grains of plagioclase, and has replaced the rims of large original plagioclase grains. Pauk (1987) reports plagioclase compositions of An_{30} to An_{42}. Pauk (1987) also reported the presence of garnet porphyroblasts in some samples. Rivers (1976) reported the localized presence of relict primary hypersthene grains mantled by hornblende in some parts of the stock. At the contacts of the intrusion, the mafic rocks are fine grained and foliated to schistose, and commonly contain blocky inclusions of neighbouring gneissic mafic and felsic rocks. Pauk (1987) observed a hornfelsic texture in adjacent rocks, which suggests the presence of a contact metamorphic aureole to the body. Contact aureoles to Lavant Suite mafic intrusions have been described by Easton and Davidson (1997) east of the synoptic area within the Sharbot Lake domain.

Of the 2 Lavant Suite intrusions in the Black Donald domain, the larger, more westerly body also contains a felsic component, consisting of quartz diorite, tonalite and granodiorite, designated as unit 17d on Map P.3443. A coeval felsic phase has been reported from other Lavant Suite intrusions, most notably from the Lavant Gabbro (Easton 1988) and, in the case of the Lavant Gabbro, the felsic phase was the same age, within analytical uncertainty, as the mafic phase (Corfu and Easton 1997).

Felsic Intrusive Rocks, Methuen Suite (unit 18)

Defined by Easton (1992b), and equivalent to the "alaskite suite" of Lumbers et al. (1990), the Methuen Suite is dominated by leucocratic pink, biotite monzogranite that typically contain accessory titanite, fluorite and magnetite. Rocks of the suite are found in all parts of the Central Metasedimentary Belt and, based on U/Pb zircon ages, were emplaced between 1250 and 1240 Ma (e.g., Easton 1992b; Corfu and

Easton 1995). The monzogranites are mainly metaluminous to marginally peraluminous. Most plutons with SiO_2 greater than 70 weight % are subalkalic, but rocks of the suite with lower silica contents may be alkalic. Lumbers et al. (1990) classified them as anorogenic granites; however, as pointed out in Davidson and Easton (1998), granites of the Methuen Suite, along with mafic intrusions of the Lavant

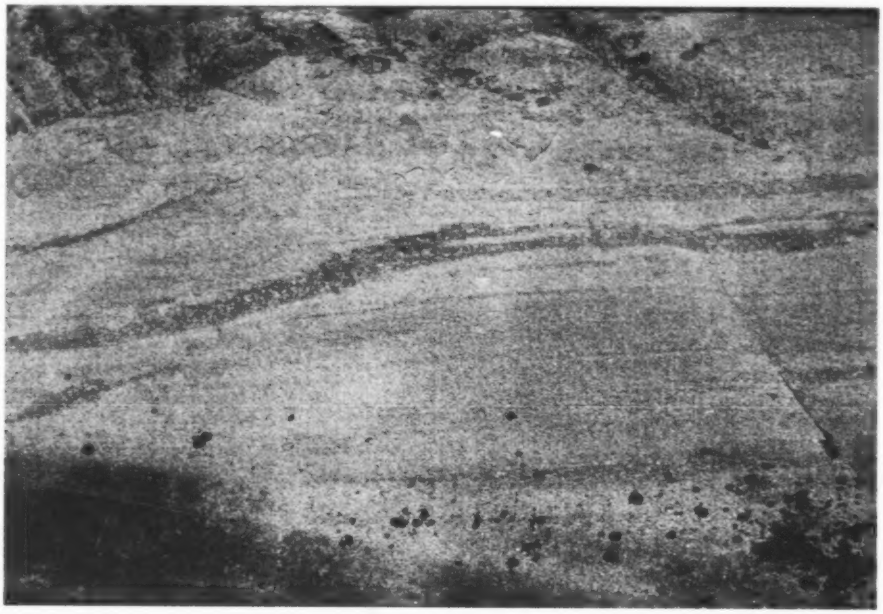

Photo 15. Granite gneiss of the Methuen intrusive suite (unit 18) at Round Schooner Lake (UTM Zone 18, 343300E 4998540N, NAD27). Geochemical analyses of this rock are listed in Appendix 1 (*see* samples 92RME-0190 and 92RME-0193). Hammer handle is 30 cm long.

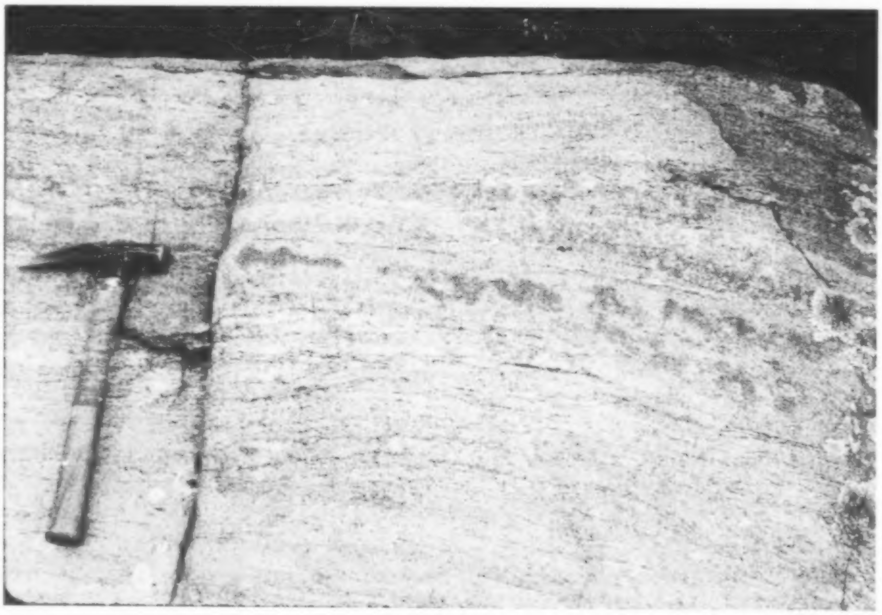

Photo 16. Migmatitic gneiss of the Methuen intrusive suite (unit 18) from the northwest part of the synoptic area (UTM Zone 18, 352160E 4996660N, NAD27). Hammer handle is 30 cm long.

Suite, appear to "stitch" the various domains of the Central Metasedimentary Belt. Consequently, both the Methuen and Lavant intrusive suites could be considered as stitching plutons emplaced during late-stage amalgamation of the Central Metasedimentary Belt at roughly 1240 Ma.

Within the synoptic area, plutons of the Methuen Suite are most prevalent north of the Shabomeka shear zone, where the pink monzogranitic rocks invade an older basement composed of amphibolite, marble, and rocks of the Killer Creek and Elzevir suites. Within Mazinaw domain, the largest pluton is the Abinger Granite. The only other sizable body is the Norway Lake granite. Two unnamed Methuen Suite plutons are found along the boundary between Mazinaw and Black Donald domains, and include a body centred on Round Schooner Lake and another body on the west shore of Brule Lake. Insufficient data are available to determine if these unnamed plutons are stitching plutons that cut the domain boundary, or if they mark the northern limit of Mazinaw domain.

ABINGER GRANITE

The most abundant metaplutonic rocks in the northern part of the synoptic area are the fine- to medium-grained, heterogeneous granites of the Abinger Granite. In the western part of the synoptic area, late, post-foliation, muscovite porphyroblasts are prevalent throughout these granitic rocks, and are probably a product of the late stages of M_2 metamorphism.

The Abinger Granite, or Abinger gneiss, (Hewitt 1964; Rivers 1976) is also commonly referred to as the Mazinaw Lake granite. The original term Abinger Granite is preferred here because the granite underlies large tracts of Abinger Township, and the term better reflects the distribution of this plutonic body. The Abinger Granite intrudes the older tonalitic and gabbroic rocks in the map area, as well as all supracrustal rocks older than the Flinton Group. This is consistent with the recently obtained U/Pb zircon age of 1240±5Ma obtained from the Abinger Granite west of Buckshot Lake (Corfu and Easton 1995).

In the northwestern part of the synoptic area, the bulk of the Abinger Granite consists of uniform, pink, fine- to medium-grained, foliated to gneissic monzogranite. The granite has a colour index of 10 or less, and is composed of plagioclase (albite or oligoclase), quartz and microcline. Common accessory minerals are biotite, magnetite, titanite, epidote, zircon and apatite. Late, fabric-cutting muscovite porphyroblasts are common within the granite. Locally, hypidiomorphic-granular texture is preserved in the granite where it is medium grained and weakly foliated (Photo 15). To the northwest, with increasing metamorphic grade, the granite becomes migmatitic (Photo 16).

Ayer (1979) reported late "albite trondhjemite" veins within the Abinger Granite in the western part of the synoptic area. These veins consist of very fine-grained, light pinkish grey biotite-microcline-albite-quartz rocks. Chemistry on these rocks, reported by Ayer (1979) and Easton (1994), indicate high silica contents in these "trondhjemites". The high silica content suggests that they may be related to the albite granites that Lumbers et al. (1990) report from both the Elzevir and Methuen suites. The low K_2O contents reported by Ayer (1979), however, remain as an unexplained curiosity. The geochemical variation within the Abinger Granite is indicated in Figure 11b.

The Abinger Granite was probably intruded as a series of closely spaced sills. Evidence for the sill-like character of the Abinger Granite is best seen on the east shore of Mazinaw Lake, south of Old Walt Rock in Bon Echo Provincial Park, where cliff-exposures provide cross-sections through the Abinger Granite. This sill-like injection pattern explains the local heterogeneity present within the granite, as well as the presence of mappable screens of older country rock throughout the Abinger Granite east of Bon Echo Provincial Park. It is also consistent with the preservation of large areas of granodiorite and tonalitic intrusion breccias within the granites where older units are mixed with injections of the Abinger Granite. Gossans are locally developed along granite–country rock contacts and in granitic intrusion breccias where zones of sulphides occur.

The sill-like injection pattern is also observed in the northeast corner of the synoptic area, where granitic sills varying from 100 to 500 m thick cut gneissic tonalites of the Elzevir Suite (unit 16n). In addition, in the northeast corner of the map area, the abrupt change in the relative abundance of gneissic tonalite (unit 16) and granite (unit 18) across the major northwest-trending faults in the area may simply be the result of exposure of different levels of the granitic sills (unit 18) and their host rocks (unit 16).

NORWAY LAKE GRANITE

The bulk of the Norway Lake granite consists of uniform, pink, fine- to medium-grained, foliated to gneissic monzogranite. The granite has a colour index of 10 or less, and is composed of plagioclase (albite or oligoclase), quartz and microcline. Common accessory minerals are biotite, fluorite, magnetite, titanite, epidote, zircon and apatite. Late, fabric-cutting muscovite porphyroblasts are common within the granite. Locally, hypidiomorphic-granular texture is preserved in the granite where it is medium grained and weakly foliated. The Norway Lake granite differs from the Abinger Granite in that purple-coloured fluorite is commonly observed in hand specimen, most likely due to the fact that the Norway Lake granite was metamorphosed at lower metamorphic grade.

FLINTON GROUP (UNITS 19 TO 23)

Introduction

In 1866, Logan introduced the term "Hastings Series" to describe rocks that he considered to be less altered equivalents of the "Grenville Series". Shortly afterward, Vennor (1870), proposed that the "Hastings Series", mainly metaconglomerates and meta-arenites, was younger than the "Grenville Series". As summarized in Table 7, this led to an ongoing debate over the stratigraphic relationships between the Grenville and Hastings "series". This debate continued even after Moore and Thompson (1972, 1980) and Thompson (1972) established that the "Hastings Series", which they renamed the Flinton Group, locally unconformably overlies the Grenville Supergroup and lacked a deformational event present in the Grenville Supergroup. Moore and Thompson (1972, 1980) also included within the Flinton Group a sequence of black sulphidic shales, calcitic and dolomitic marbles, and marble breccias and conglomerates (Myer Cave Formation) and calcareous and clastic rocks (Fernleigh Formation)—units that had not previously been considered part of the "Hastings Series".

In the mid-1980s, the age and unconformable nature of the Flinton Group was questioned by several studies (e.g., Connelly 1985; Connelly, van Breemen and Hanmer 1987; Abdel-Rahman and Martin 1987), in part because of the presence of similar structural fabrics in both the Grenville Supergroup and related metaplutonic rocks and the Flinton Group. It was argued that because the Elzevir and Addington plutons had similar fabrics to those present in the Flinton Group, the Flinton Group had to have a maximum age of deposition older than the U/Pb zircon ages of these bodies, that is, older than circa 1270 and 1245 Ma, respectively. These ages increased the maximum age of the Flinton Group to roughly 1245 Ma, which was considerably older than the previous estimate of 1090 Ma based mainly on Rb/Sr ages (Moore and Thompson 1980). Until additional information was acquired, this led to speculation that the Flinton Group was similar in age to parts of the Grenville Supergroup.

There is now consensus that the Flinton Group unconformably overlies older supracrustal and metaplutonic rocks, in part based on mapping conducted during this study (e.g., Easton and Ford 1991). Furthermore, U/Pb dating of detrital zircons from quartz arenite of the Bishop Corners Formation of the Flinton Group (Kinsman and Parrish 1990; Sager-Kinsman and Parrish 1993) showed a population of 1180 to 1150 million-year-old zircons, indicating that the maximum age of the Flinton Group is at least 80 to 100 million years younger than the underlying Grenville Supergroup, supporting Moore and Thompson's (1980) separation of the Flinton Group from the Grenville Supergroup and their contention that the Flinton Group was significantly younger than the Grenville Supergroup.

Table 7. History of stratigraphic nomenclature related to the Flinton Group in the Central Metasedimentary Belt.

Reference	Stratigraphic Name and Interpretation
Logan (1846)	Grenville Series north of Ottawa River.
Logan (1866)	Hastings Series is less altered equivalent of Grenville Series.
Vennor (1870)	Hastings Series is younger than Grenville Series.
Adams et al. (1907)	Hastings Series is part of Grenville Series, but name should be retained to indicate difference in metamorphic grade; term Hastings Series applied to all relatively low-grade supracrustal rocks in Ontario.
Miller and Knight (1914)	Hastings Series is unconformable on Grenville Series in southeastern Ontario; Grenville and Hastings series correlated with Keewatin and Temiskaming series, respectively.
Meen (1944), Harding (1944)	Hastings and Grenville rocks separated, but assigned to one group. Both intruded by plutons.
Burns (1951), Ambrose and Burns (1956)	Distinction between Hastings and Grenville considered unwarranted; introduced term Flinton Group for conglomerates in Flinton syncline.
Smith (1958)	Distinguished some sedimentary units, now defined as part of the Flinton Group from older supracrustals. Recognized unconformity between granite and conglomerate near Plevna Lake, but in Smith et al. (1969) suggested contact was intrusive, not an unconformity.
Bain (1960), Lumbers (1964, 1967b), Hewitt (1964, 1968), Hewitt and James (1956)	Supracrustals assigned to Grenville Series, divided into Hermon and Mayo groups (and a variety of formations); some strata now assigned to Flinton Group included in this scheme. Plutonic rocks considered to postdate all supracrustal rocks.
Wynne-Edwards (1967)	First use of term Grenville Group (instead of Series).
Wynne-Edwards (1972), Moore and Thompson (1972), Thompson (1972)	Grenville Supergroup established. Flinton Group noted as unconformable on Mayo and Hermon groups, but considered part of Grenville Supergroup. Regional correlations presented in Wynne-Edwards (1972). Bishop Corners, Myer Cave, Fernleigh and Lessard formations established. Flinton Group postdates plutonic rocks.
Bright (1976, 1977, 1987)	Established several new formations in the Harvey–Cardiff Arch, which Bright correlates with Hermon and Mayo groups. Establishes Anstruther Lake Group, an arkosic sequence that underlies the Hermon Group.
Chappell (1978)	Established several stratigraphic terms in the Clare River area and correlates units with Hermon and Flinton groups.
Moore and Thompson (1980)	Flinton Group formally defined with type sections. Flinton Group defined as postdating Grenville Supergroup. Ore Chimney Formation (Grenville Supergroup) defined as regolith underlying Bishop Corners Formation. Correlations made with Madoc area where Madoc and Stewart formations are defined.
Bartlett (1983), Bartlett and Moore (1985)	Define several formations in Belmont Lake area for supracrustal succession.
Abdel-Rahman and Martin (1987), Easton (1989)	Suggest Flinton Group correlatives in Madoc area older than 1241 Ma Deloro Granite. Easton (1989) suggests Madoc and Stewart formation are unaltered Grenville Supergroup rocks (as did Adams et al. 1907) and recommends abandonment of these units, as well as other disused stratigraphic terms in the Central Metasedimentary Belt.
Kinsman (1990), Sager-Kinsman and Parrish (1993)	Maximum U/Pb age of 1157±3 Ma on deposition of Bishop Corners Formation meta-arenite confirms that the Flinton Group is considerably younger than the Grenville Supergroup.
Easton and Ford (1991), F.D. Ford (personal communication of unpublished data, 1992)	Refinement of Myer Cave Formation stratigraphy in Fernleigh area. Expand Flinton Group to include other metaconglomerates and metapelites in the Fernleigh–Plevna area not previously included in the Flinton Group. Confirm presence of unconformity and regolith below the Bishop Corners Formation.
Corfu and Easton (1994, 1995)	Time of metamorphism of pelitic units within the Flinton Group dated at circa 1020 Ma by U/Pb zircon ages.
This study	Suggest that the conglomerate/arenite and pelite/carbonate sequences of the Flinton Group are separate in time and space, and possibly origin as well as suggesting geochemical discrimination of Flinton Group pelites and carbonates from the Grenville Supergroup.

Although not a volumetrically large unit within the synoptic area, the Flinton Group is regionally extensive. Furthermore, its unconformable relationship with the Grenville Supergroup, its sedimentological variety (including possible paleosols, metaconglomerates and meta-arenites, metapelites and marbles), its range of distinctive metamorphic indicator minerals, and its spatial (and genetic?) association with mineralization all combine to make the Flinton Group a key unit in understanding the tectonic history and the mineral potential of the synoptic area.

Stratigraphy

OVERVIEW

Moore and Thompson (1972, 1980) described the Flinton Group as a distinctive succession of metaconglomerate, metaquartzarenite and metapelite. Although Ambrose and Burns (1956) had introduced the term Flinton Group for some, but not all, metaconglomeratic rocks in the Kaladar area to the south of the synoptic area, it was not until the 1970s that Moore and Thompson (1972, 1980) formalized the stratigraphy of this sequence of metasedimentary rocks by formally defining the Flinton Group, and several distinctive formations (*see* Table 4). Moore and Thompson (1972, 1980) also noted the presence of carbonate within the Flinton Group, namely the Myer Cave, Lessard and Fernleigh formations, and showed the true areal extent of the Flinton Group. Photos 17 to 35 illustrate the variety of rock types present within the Flinton Group in the synoptic area.

Map P.3443 shows the distribution of Flinton Group strata within the Mazinaw domain. The Flinton Group locally lies unconformably on rocks of the Mazinaw ("Grenville") Group and the Elzevir and Methuen plutonic suites. The Flinton–Mazinaw groups unconformity is locally preserved. In addition, mafic dikes common in the Mazinaw Group and older plutons do not cut the Flinton Group and, other than a few late syenite pegmatite dikes and muscovite-plagioclase-quartz veins, no intrusions cut the Flinton Group (Moore and Thompson 1980). These observations are all consistent with the unconformable nature of the Flinton Group.

Table 4 summarizes the stratigraphy of the Flinton Group, and is adapted from Moore and Thompson (1980). Chappell (1978) proposed 2 formations in the Clare River area, the Beatty and Bogart formations, which are roughly correlative with the Bishop Corners and Lessard formations (*see* Table 4). Bright (1986) mapped the Flinton Group in the Clare River area in detail, but did not use Chappell's stratigraphy. Table 4 includes subdivision of the Myer Cave Formation into 5 members, as originally suggested by F.D. Ford (personal communications, 1990 and 1991) and as published in Easton and Ford (1991). In addition, metaconglomerates and metalitharenites in the Ompah area have been separated into a distinctive unit, the Ompah Formation, because they were subjected to folding and deformation not present in other Flinton Group units in the Ompah area (Ford 1992); they are petrographically and geochemically distinctive. At this juncture, it is unclear if the Ompah Formation is correlative with the conglomerate-arenite member of the Bishop Corners Formation or is a separate unit.

Moore and Thompson (1972, 1980), Harnois (1988a) and Harnois and Moore (1988) described a regolith locally preserved beneath the Flinton Group. The regolith is preserved as a biotite-garnet ± staurolite ± hornblende schist termed the Ore Chimney Formation (Moore and Thompson 1980), which is part of the Mazinaw Group. Although defined by Moore and Thompson (1980) as part of the Grenville Supergroup, the Ore Chimney Formation is described with the Flinton Group because of the spatial relationship of the 2 units and because the origin of the Ore Chimney Formation might be related to the processes responsible for Flinton Group deposition.

Rocks directly correlative with the Flinton Group are apparently absent within the adjacent Elzevir and Bancroft terranes, and the Sharbot Lake domain. The restriction of the Flinton Group to the Mazinaw domain (Elzevir Terrane of Moore 1982) is anomalous, because it means that this unconformable sequence is only preserved in a structurally complex, high-grade part of Moore's (1982) Elzevir Terrane. Even if the Mazinaw domain has had a unique and separate geologic history compared to the Elzevir terrane, then the restriction of the Flinton Group to the Mazinaw domain is not readily explained.

As discussed later in this section, there is some indication that the conglomerate and meta-arenite sequence (Bishop Corners Formation, Ompah Formation) may be separate in time and space from the pelite and carbonate sequence (pelite member of the Bishop Corners Formation, Myer Cave and Fernleigh formations). It is unclear if this is due to a disconformity in the stratigraphic sequence or, alternatively, whether 2 separate and unrelated stratigraphic sequences comprise the Flinton Group as it is currently defined.

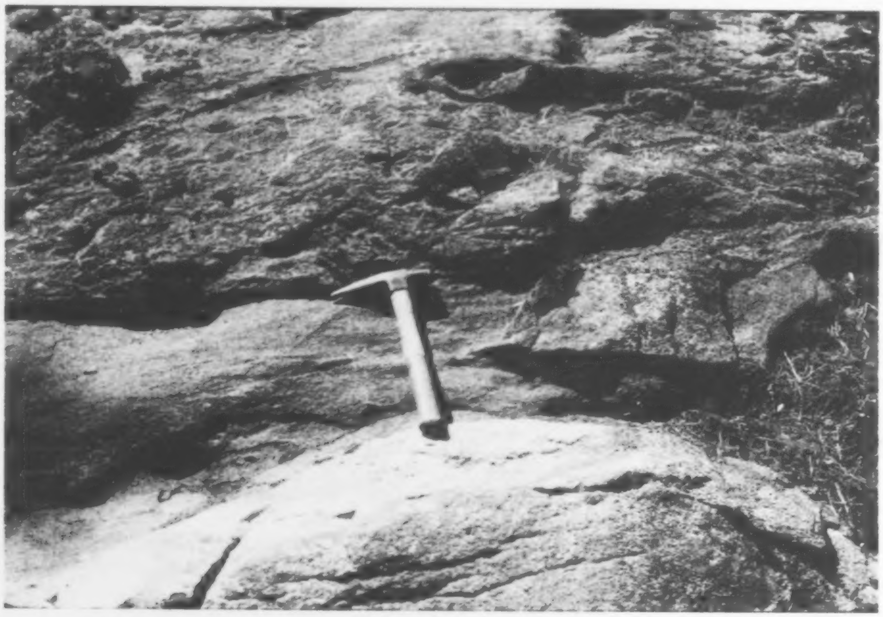

Photo 17. Norway Lake Formation–1. Unconformity with Norway Lake granite (bottom, beneath hammer). Meta-arenite with large angular granite block (right of hammer) immediately overlies the granite. The meta-arenite is overlain in turn by conglomerate containing rounded and angular granite clasts (UTM Zone 18, 336950E 4974575N, NAD27). Hammer handle is 30 cm long.

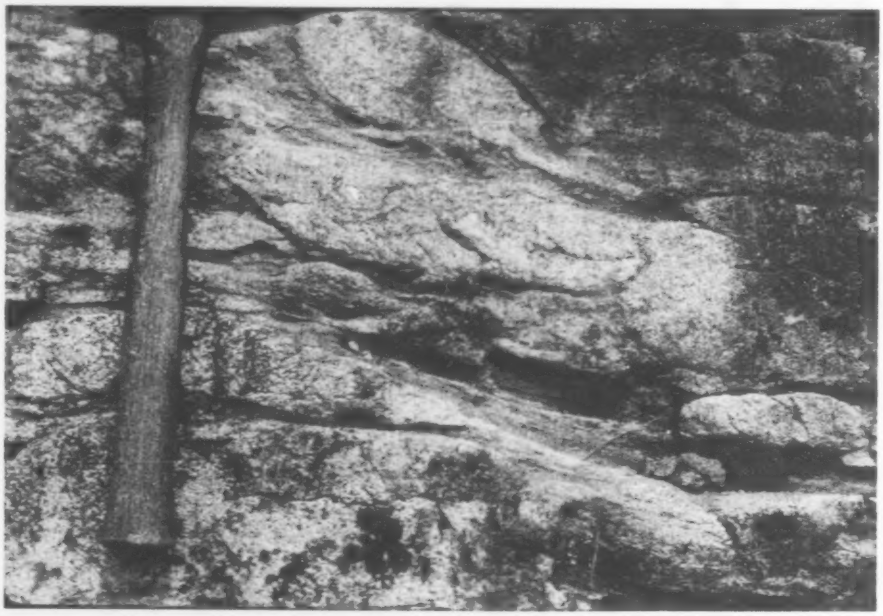

Photo 18. Norway Lake Formation–2. Blocky granite clasts in feldspathic litharenite, roughly 10 m above contact with Norway Lake Granite south of Shawenegog Lake (UTM Zone 18, 336950E 4974575N, NAD27). Hammer handle is 30 cm long.

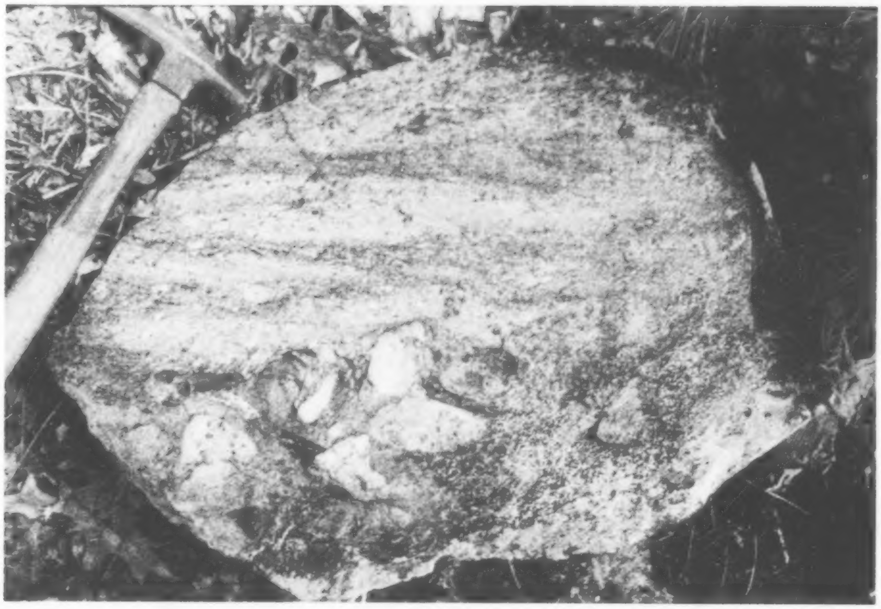

Photo 19. Norway Lake Formation–3. Conglomerate lens in semi-pelite to pelite unit intercalated with conglomerate units above the Norway Lake Granite south of Sand Lake (UTM Zone 18, 340385E 4975920N, NAD27). Hammer handle is 30 cm long.

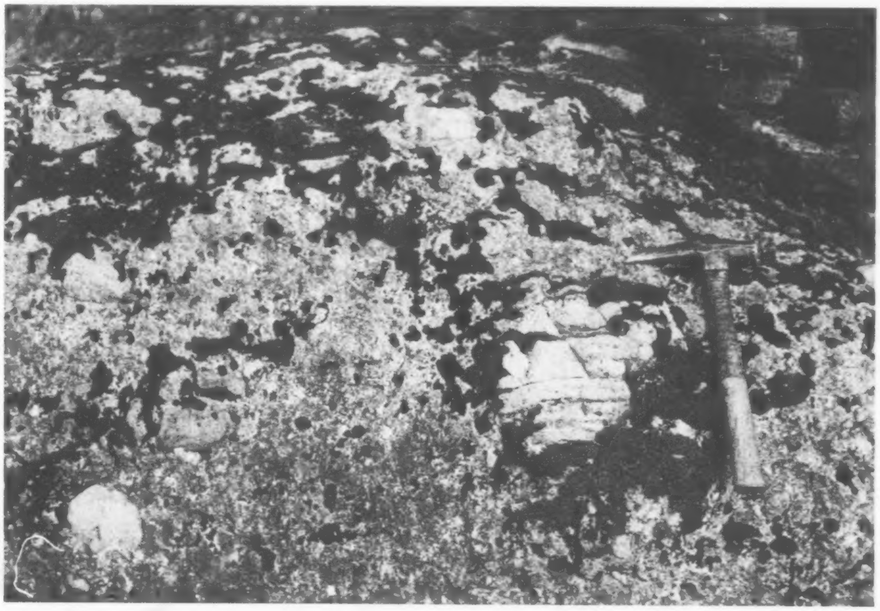

Photo 20. Norway Lake Formation–4. Large, subrounded granite clast to the left of the hammer, hosted in matrix-supported conglomerate above the Norway Lake Granite south of Sand Lake (UTM Zone 18, 340385E 4975920N, NAD27). Hammer handle is 30 cm long.

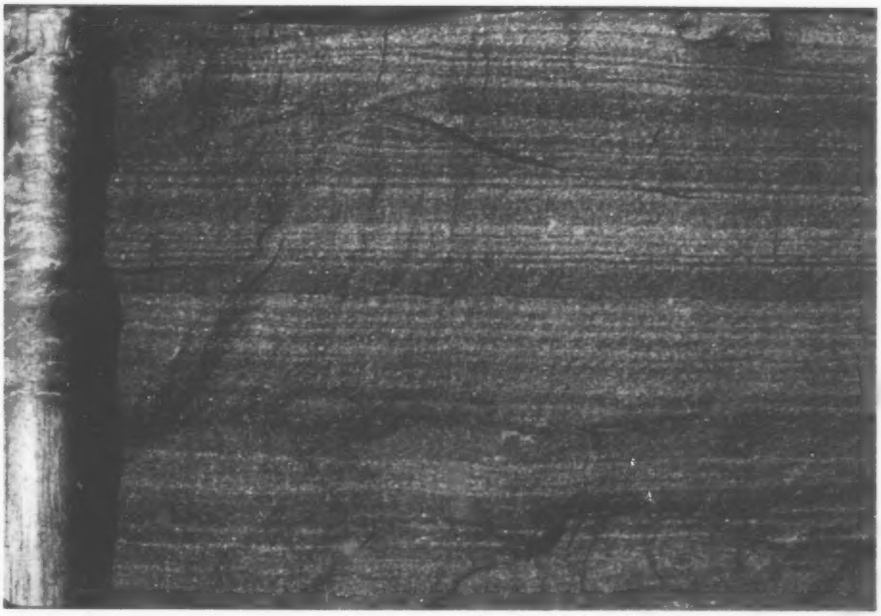

Photo 21. Myer Cave Formation–1. Finely laminated, black sulphidic shale of the laminated member, on Frontenac County road 506 near Green Bay (UTM Zone 18, 334979E 4968991N, NAD27). Field of view is 15 cm across. Bright spots are pyrite grains.

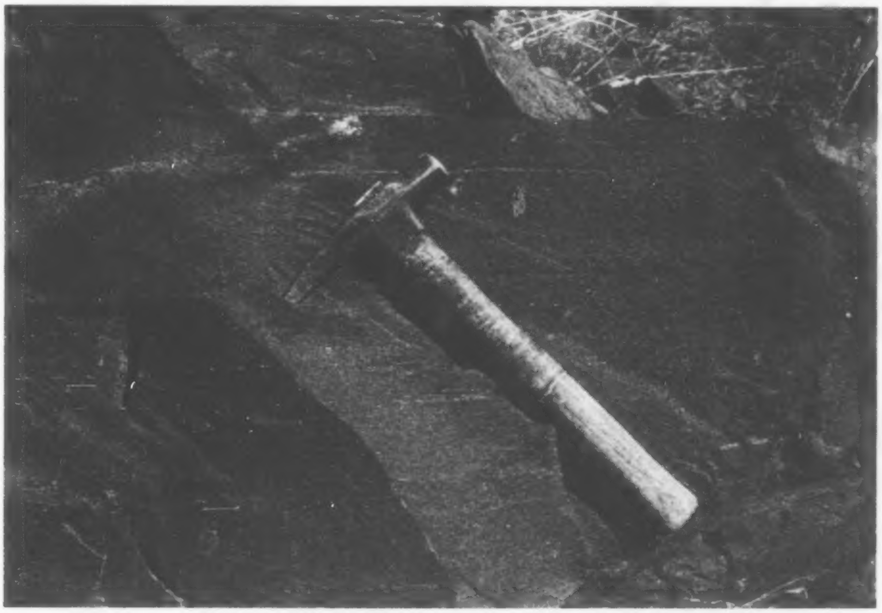

Photo 22. Myer Cave Formation–2. Unlaminated, black sulphidic shale of the unlaminated member, on Frontenac County road 506 near Fernleigh (UTM Zone 18, 341812E 4973499N, NAD27). Hammer handle is 30 cm long.

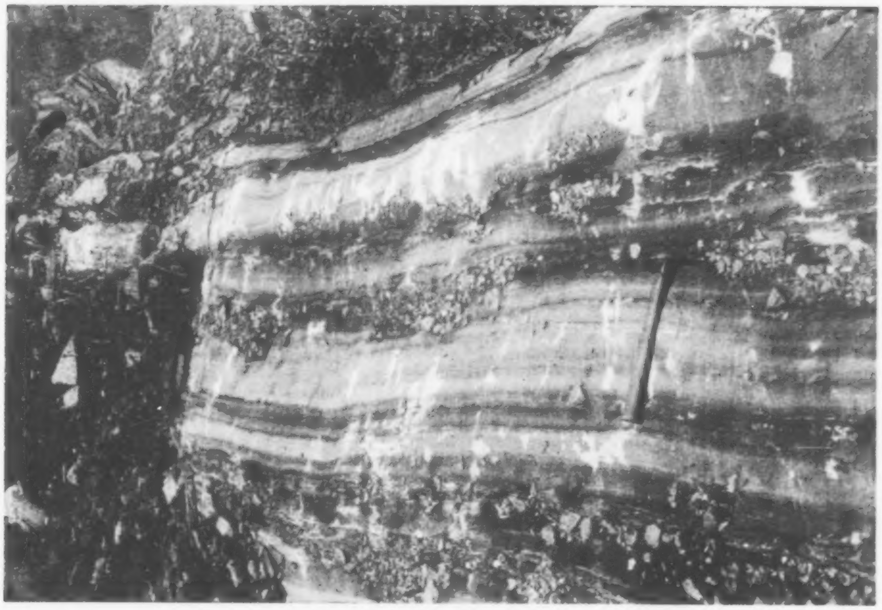

Photo 23. Myer Cave Formation–3. Thin- to medium-bedded calcite turbidites of the calcareous member, on Frontenac County road 506 west of Fernleigh (UTM Zone 18, 344126E 4974625N, NAD27). Hammer handle is 30 cm long.

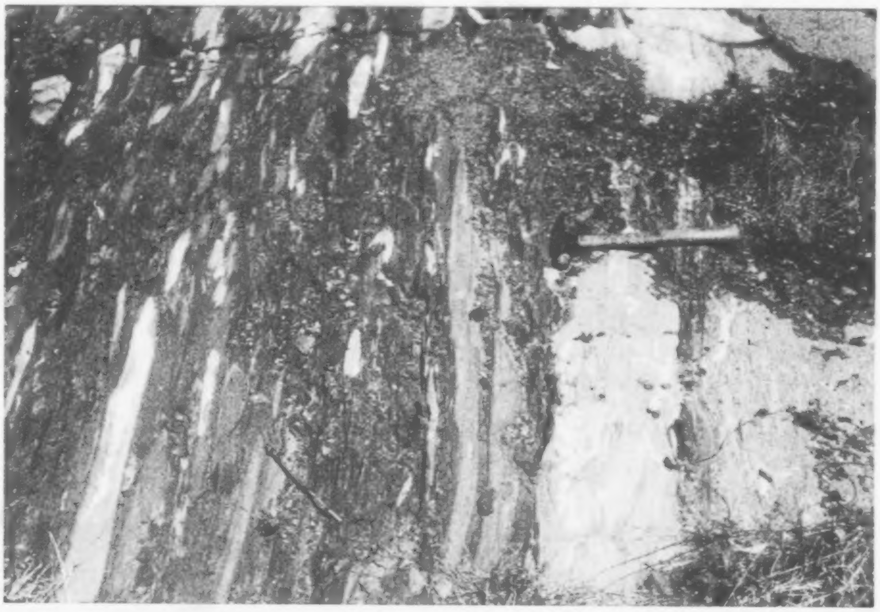

Photo 24. Myer Cave Formation carbonate megabreccia unit–1. Note variety of carbonate clast types and sizes (UTM Zone 18, 334250E 4968350N, NAD27). Hammer handle is 30 cm long.

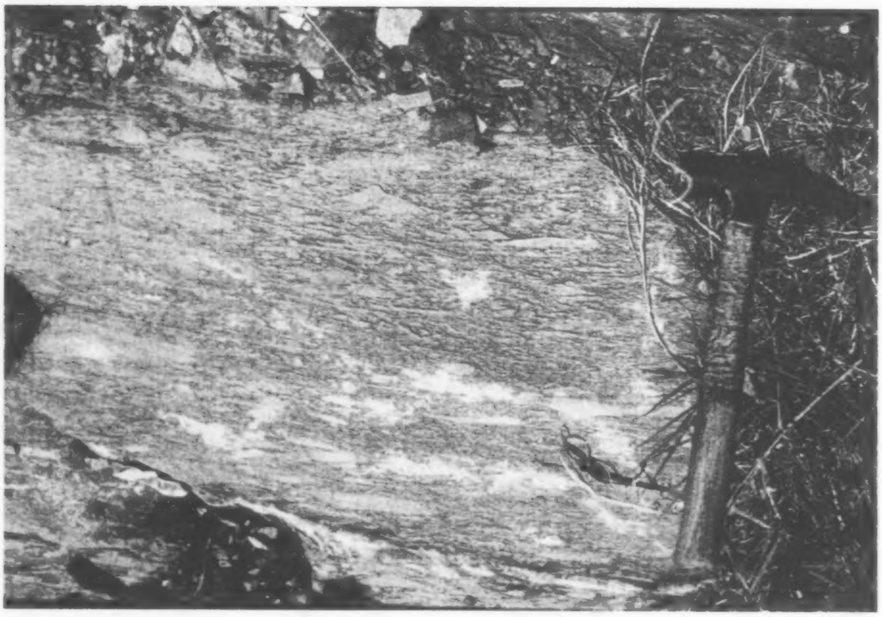

Photo 25. Myer Cave Formation carbonate megabreccia unit–2. Close-up of block left of hammer in Photo 24, showing well-preserved textures in block of calcite carbonate breccia within the megabreccia unit. This clast may be intraformational in origin, based on its degree of preservation (UTM Zone 18, 334250E 4968350N, NAD27). Hammer handle is 30 cm long.

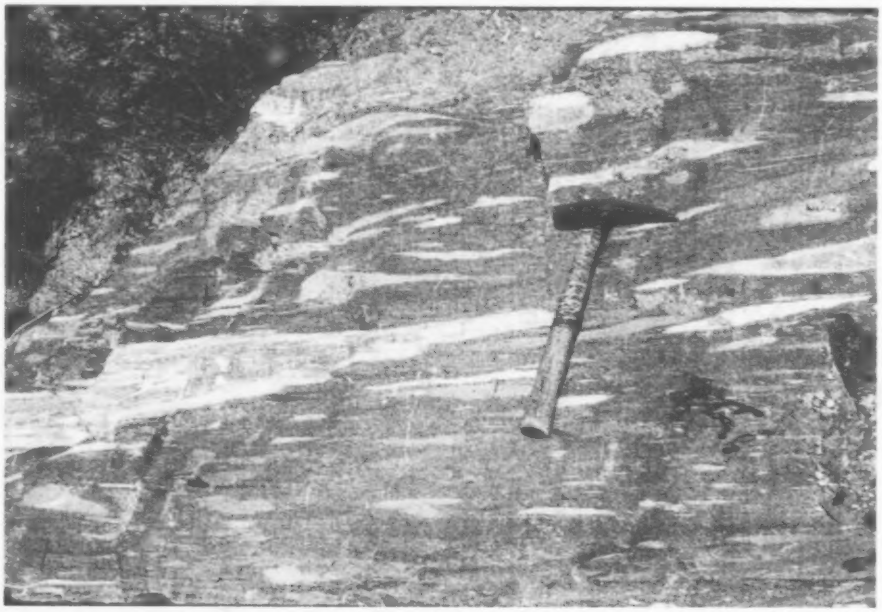

Photo 26. Myer Cave Formation carbonate megabreccia unit–3. Massive dolomite marble clasts within the megabreccia unit. These clasts lie adjacent to the clast shown in Photo 25, and presumably were dolomite prior to incorporation into the megabreccia (UTM Zone 18, 334250E 4968350N, NAD27). This suggests a pre-Flinton Group metamorphic event. Hammer handle is 30 cm long.

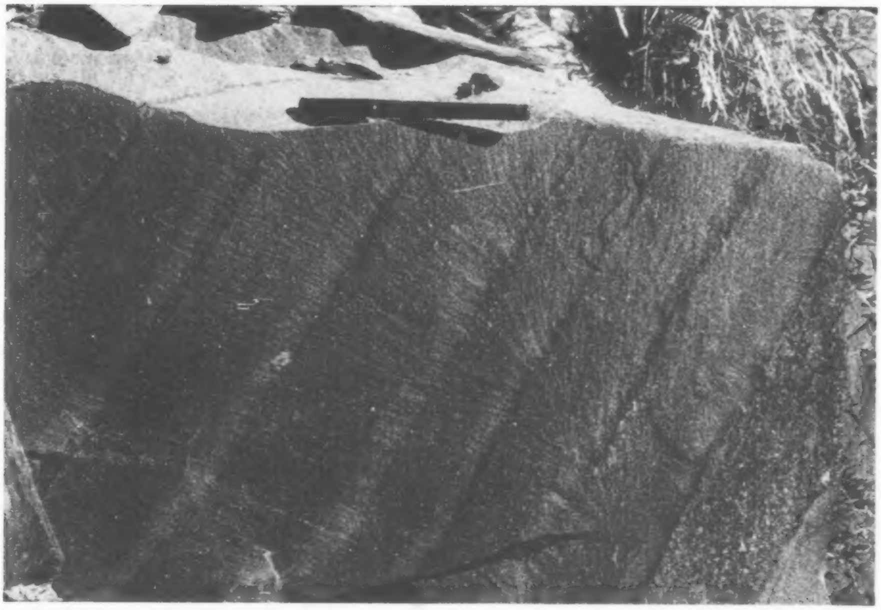

Photo 27. Myer Cave to Fernleigh Formation. Medium-bedded, sulphidic shale from the transitional contact between the Myer Cave and Fernleigh formations along Frontenac County road 506 east of Fernleigh (UTM Zone 18, 340460E 4972460N, NAD27). Pen is 14 cm long.

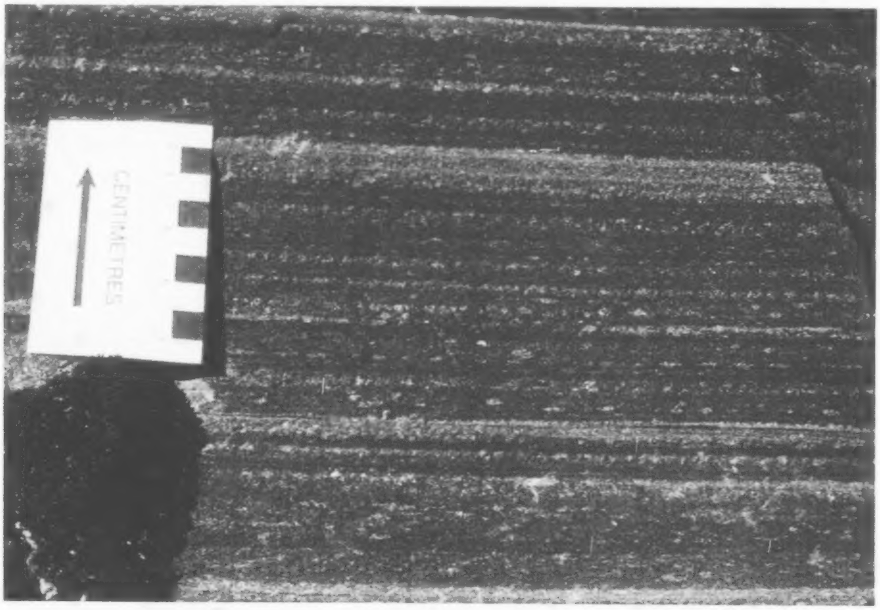

Photo 28. Fernleigh Formation. Thin-bedded calcareous shale of the Fernleigh Formation along Frontenac County road 506 west of Fernleigh showing typical bedding in unit (UTM Zone 18, 347854E 4976477N, NAD27). Spots are microcline porphyroblasts. Scale card marked in cm.

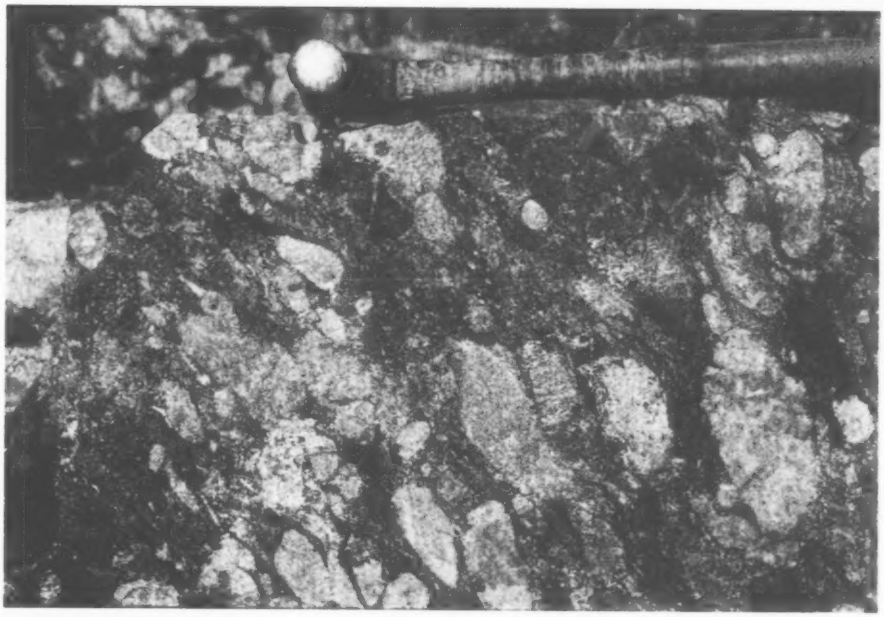

Photo 29. Ompah Formation. Clast-supported conglomerate, containing abundant tonalite, granite and carbonate clasts, south of Ompah (UTM Zone 18, 356874E 4982787N, NAD27). A chemical analyses of the matrix to this conglomerate is reported in Appendix 1 (*see* sample 95RME-0096). Hammer handle is 30 cm long.

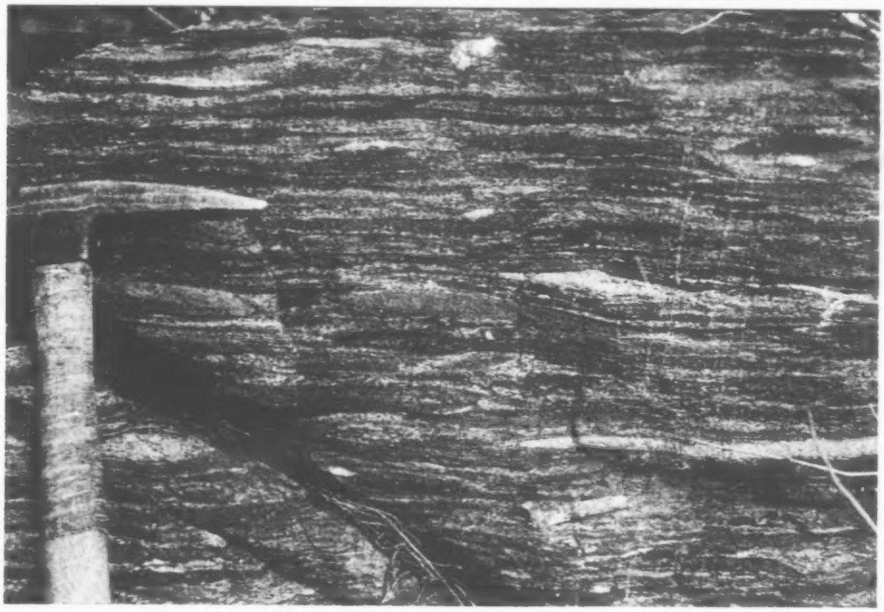

Photo 30. Ompah Formation. Flattened, matrix-supported conglomerate, containing abundant tonalite, granite and carbonate clasts, west end of Sunday Lake, northeast of Ompah. Hammer handle is 30 cm long.

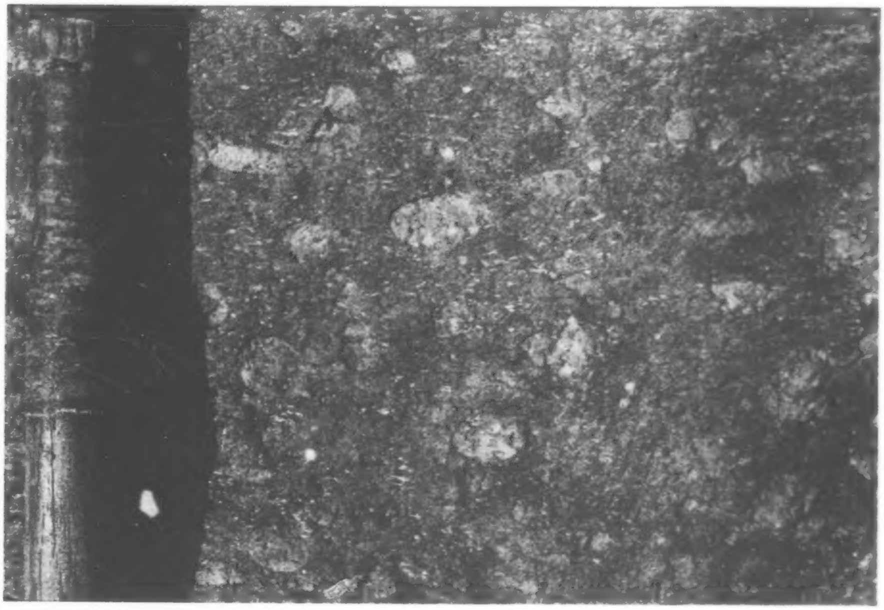

Photo 31. Metamorphic grade–1. Large microcline porphyroblasts in calcareous shale of the Fernleigh Formation, near Ardoch (UTM Zone 18, 343188E 4974460N, NAD27). Field of view is 20 cm across.

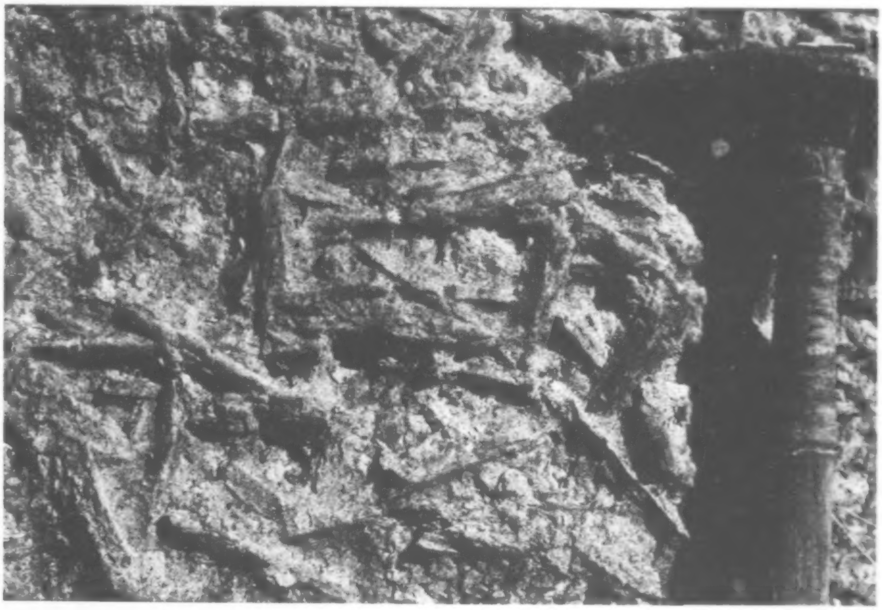

Photo 32. Metamorphic grade–2. Kyanite porphyroblasts in Bishop Corners Formation pelite. Field of view is 10 cm across. Location withheld to preserve outcrop.

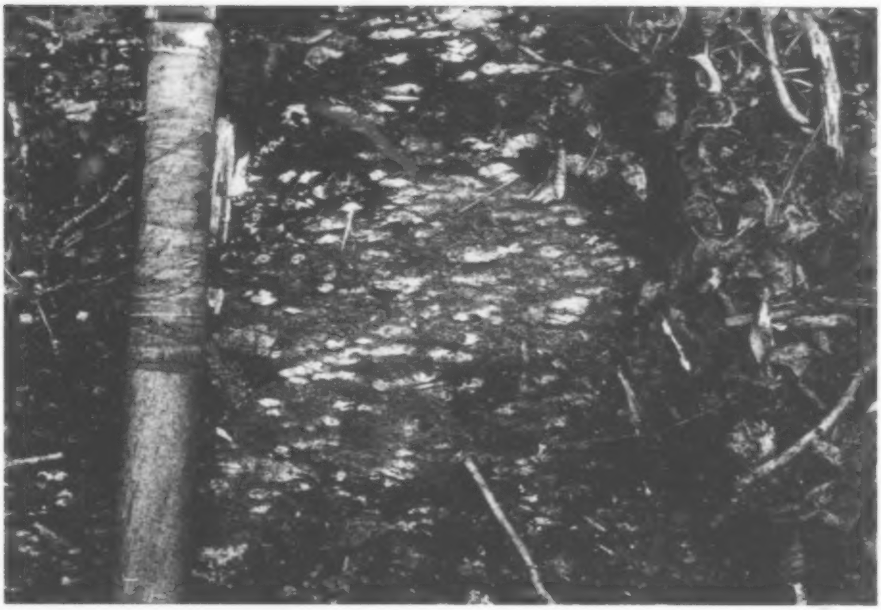

Photo 33. Metamorphic grade–3. Large sillimanite clots (white) in biotite-garnet-sillimanite schist, Myer Cave Formation, Mosque Lake (UTM Zone 18, 349700E 4984760N, NAD27). A chemical analyses of this rock is provided in Appendix 1 (*see* sample 92RME-0068). Hammer handle is 30 cm long.

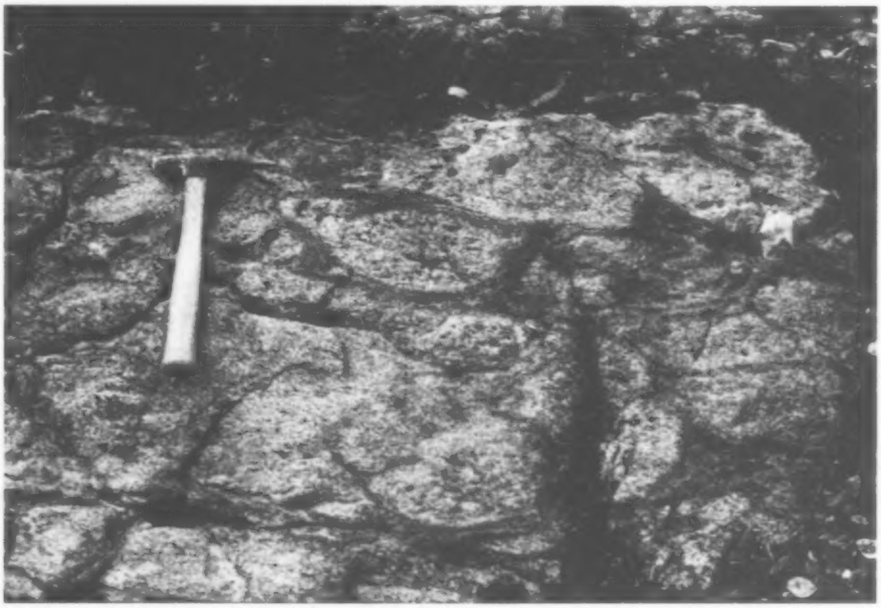

Photo 34. Ore Chimney Formation. Altered pillow lavas of the Kashwakamak Formation beneath Flinton Group west of Marble Lake (UTM Zone 18, 330090E 49653985N, NAD27). These pillows are texturally similar to the pillow shown in Photo 2. Hammer handle is 30 cm long.

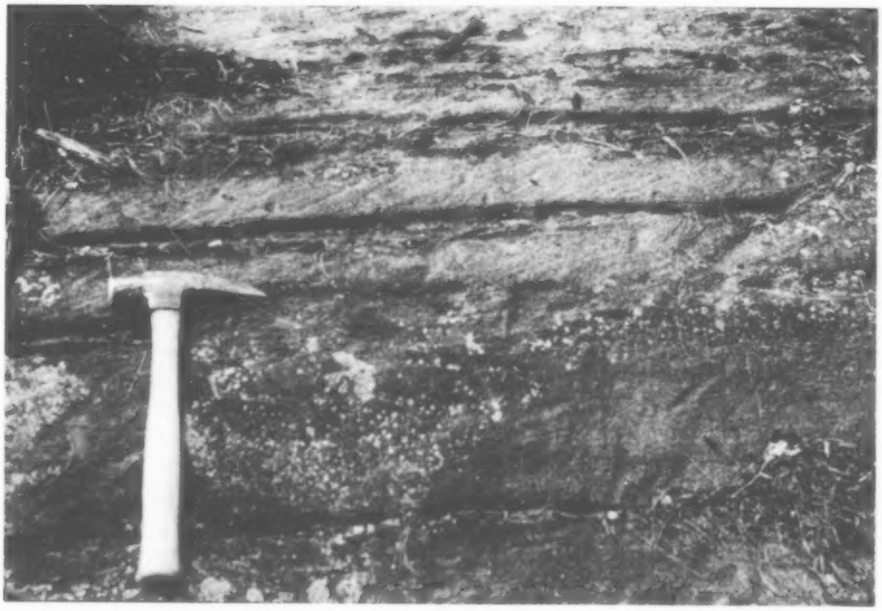

Photo 35. Ore Chimney Formation to Bishop Corners Formation transition west of Marble Lake. Development of thin- to medium-bedded arenite and pelite (upper part of photograph) above more massive rock. Approximately 10 m stratigraphically above rock shown in Photo 34 (UTM Zone 18, 330090E 49653985N, NAD27). A chemical analyses of this unit is provided in Appendix 1 (*see* samples 91RME-0188B, 91RME-0188C). Hammer handle is 30 cm long.

MAP PATTERN AND STRUCTURAL RELATIONS WITH UNDERLYING UNITS

The structural relationship between the Flinton Group and the underlying Grenville Supergroup and metaplutonic rocks presents many incongruities that are currently not well understood. For example, Moore and Thompson (1972, 1980) noted that the Flinton Group is preserved in tight, isoclinally folded synclines throughout the Mazinaw domain. However, where unconformable relationships are best developed with underlying units (Sand and Norway lakes areas, Kaladar metaconglomerate), synclines are not observed, and the overlying metaconglomerates have a tabular form that mimics topography.

Another incongruity is that the penetrative fabric in the Flinton Group appears to be better developed in the Flinton Group than in underlying units. In the Sand Lake[3] area, at the granite–conglomerate contact, the penetrative foliation in the Flinton Group dips shallowly to the southeast at roughly 20 to 30°. This fabric is not readily apparent in the structurally and topographically underlying granite, yet, within the Flinton Group, steepens to 70 to 80° only a few tens of metres to the southeast. However, the map pattern and facies distribution within the Flinton Group at this locality is suggestive of a thin, tabular body that overlies underlying strata, which is visible in topographically low-lying "windows". Similar relationships are present in the vicinity of the Dome gold occurrence in the Marble Lake area (Moore and Morton 1986). Thus, the map pattern seems inconsistent with the penetrative fabric.

In fact, this similarity in structural fabrics between the Grenville Supergroup and metaplutonic units and the Flinton Group led Connelly (1985, 1987) and Connelly, van Breemen and Hanmer (1987) to argue on structural grounds that the Flinton Group was in structural contact with the underlying units, was possibly older than the Elzevir Tonalite, and was likely tectonically emplaced at roughly 1229 Ma.

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[3] Sand Lake was formerly named Plevna Lake.

Although subsequent geochronology has shown the Flinton Group to be much younger (Sager-Kinsman and Parrish 1993; Corfu and Easton 1995), the earlier studies of Connelly and co-workers serves to illustrate the problem in recognizing and interpreting fabrics present in both the Flinton Group and underlying rock units.

Similarly, in the Fernleigh belt, particularly along the southeastern contact of the belt, the penetrative fabric is inconsistent with the map pattern. As noted above, the sequence appears to be a steeply dipping homocline. If the penetrative fabric reflects the true attitude of the Flinton Group strata, then the contact with the Grenville Supergroup must be a fault, either downthrown to the north or an oversteepened thrust. There is no indication of a fault along this contact, and the map pattern of the Flinton Group in the Fernleigh belt in the Marble Lake area has the appearance of a thin, tabular, cover sequence. One possible explanation is that the penetrative fabric observed in the Flinton Group developed early during M_2 prior to major metamorphic mineral growth and that fabric development in the underlying strata was inhibited by the previous high-grade metamorphism (M_1) imposed on these rocks. Consequently, the penetrative fabric in the Flinton Group is restricted to the Flinton Group, and does not reflect regional structures, and that the map pattern of the Flinton Group more accurately reflects its unconformable, cover relationship to the underlying strata.

FLINTON GROUP IN THE SYNOPTIC AREA

Four of the originally defined formations of the Flinton Group (*see* Table 4)—the Bishop Corners, Ompah, Myer Cave, and Fernleigh formations—crop out within the synoptic area. Rocks of the Lessard Formation are exposed in the Flinton syncline immediately southwest of the synoptic area, and are not discussed in detail in this report. In addition, a new formation, the Norway Lake Formation, has also been identified within the synoptic area.

The bulk of the Flinton Group strata in the synoptic area are located in a linear, 0.5 to 2 km wide, east-northeast-trending belt—the Fernleigh belt (*see* Figures 4 and 5)—termed the Fernleigh "syncline" by Moore and Thompson (1972, 1980). In the Ompah area, a second linear belt lies south of the Fernleigh belt, and has been termed the Ompah structure by Ford (1992), or the Ompah "syncline" by Smith (1958, 1969), Moore and Thompson (1972, 1980) and Pauk (1983, 1987). In addition, several discontinuous belts of Flinton Group strata occur marginal to the Norway Lake granite, north of Little Green Lake and in the vicinity of Mosque Lake.

Fernleigh Belt

Figure 12 summarizes the facies relationships between the various members and formations of the Flinton Group within the Fernleigh belt in the Cloyne to Ardoch area. Moore and Thompson (1972, 1980) and Moore and Morton (1986) describe the Fernleigh belt as an overturned, tight to isoclinal syncline. From Marble Lake northward, stratigraphic units are not repeated across the syncline and rapid lateral facies changes across the Flinton Group were invoked by Moore and Thompson (1972, 1980) to explain this lack of stratigraphic repetition. Rivers (1976), in studying the Fernleigh belt in the Fernleigh–Ompah area, found no evidence that it was a syncline, or even synformal, and concluded that it was a steep, southeast-facing overturned homoclinal sequence. Mapping in the Bishop Corners to Fernleigh part of the belt as part of this study confirms Rivers' (1976) interpretation, at least for the segment of the belt located northeast of Marble Lake. For example, south of Myer Cave, recent road construction has exposed an almost continuous section through the Myer Cave Formation. Marble breccias within the Myer Cave Formation in this section fine upward, and are overlain by pelites characteristic of the uppermost Myer Cave Formation (the Unlaminated Schist member, *see* below). Thus, the stratigraphy exposed there appears to be a continuous, northwest-dipping, southeast-facing homoclinal sequence, and there is no stratigraphic or structural evidence for a synclinal or synformal structure as far west as Marble Lake even in the southern, less deformed and metamorphosed part of the Fernleigh belt.

The geology of the Fernleigh structure in the northeastern part of the synoptic area near Ompah has been documented by Smith (1958), Moore and Morton (1986) and Pauk (1983, 1987, 1989b). Frontenac County road 509, east of Ompah, provides a representative section through the Flinton Group. A detailed description of this section is warranted because increasing deformation and metamorphism make the stratigraphy less recognizable to the northeast, an observation also made by Moore and Thompson (1972) and Rivers (1976).

In the Ompah area, the basal unit on the northern limb of the Fernleigh belt is a muscovite-rich pelite of the Bishop Corners Formation. This unit strikes approximately 045° and is well exposed up-strike along the power line which extends to the northeast. In thin section, this unit contains mostly quartz, muscovite and biotite, with porphyroblasts of oxide minerals and radiating sillimanite needles. The unit displays some evidence of retrograde metamorphism. Most biotite grains have been altered to chlorite containing a fine mat of rutile needles. This retrogression, and other alteration such as epidotization of Ompah Formation metaconglomerate at the west end of Sunday Lake, may be associated with the Fernleigh–Clyde fault, identified by Smith (1958). The fault trends northeast, subparallel to the northern margin of the Fernleigh structure and can be traced as a prominent airphoto lineament. The Fernleigh–Clyde fault may be similar in age to other northwest- and west-trending faults in the area (*see also* Easton 1992c, 1993). Truncation of the Bishop Corners pelite near the west end of Sunday Lake, suggests that a component of fault movement is dextral. It should be noted that several previous workers (Moore and Thompson 1972; Rivers 1976; Pauk 1983) have questioned the existence of the Fernleigh–Clyde fault.

A thin unit of Myer Cave Formation pyritic biotite schist overlies the muscovite pelite. This rock is fine grained and massive with no visible bedding. The pyritic schist is overlain by coarse-grained calcite marble of the Myer Cave Formation. The marble is indistinguishable from surrounding Grenville Supergroup marbles and is assigned to the Flinton Group on the basis of mapped position (it lies between Bishop Corners Formation muscovite pelite and Fernleigh Formation calc-silicate schist). The marble is overlain by an interbedded sequence of compositionally varied, fine-grained, biotite schists of the middle part of the Myer Cave Formation. Compositional layering occurs on a metre scale and may reflect primary bedding. Some layers are garnet rich, whereas others contain sulphide (typically pyrite).

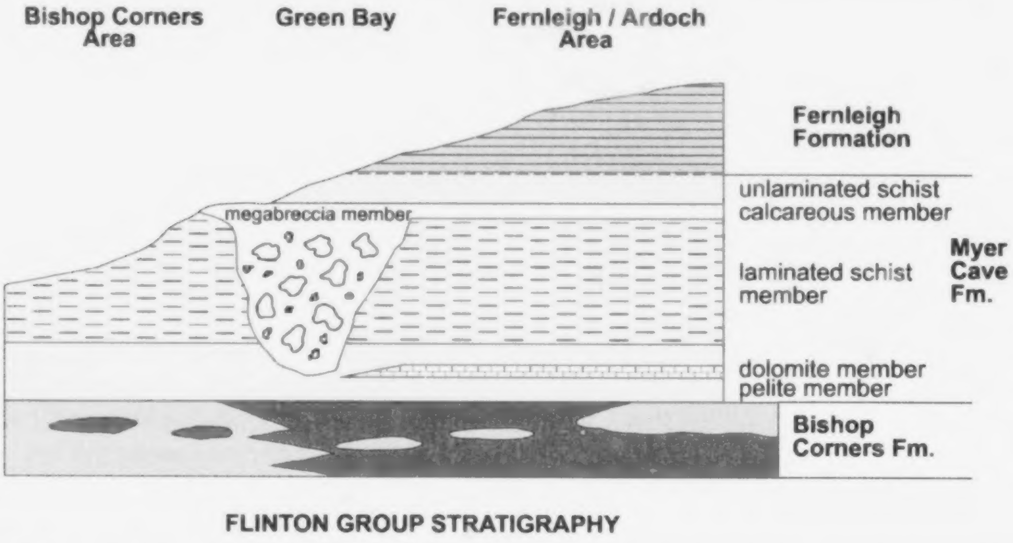

Figure 12. Stratigraphic relationships within Flinton Group strata in the Fernleigh belt between the Bishop Corners and Ardoch areas, southwestern part of the synoptic area.

The upper part of the Myer Cave Formation is a distinctive garnet-biotite-sillimanite pelite, similar to Myer Cave Formation pelites previously mapped to the southwest (F.D. Ford, personal communication of unpublished data, 1992; Easton and Ford 1991). Myer Cave Formation pelites have a uniform, iron-rich bulk composition, and are rich in biotite and garnet, whereas Bishop Corners Formation pelites are more aluminous, muscovite rich and span a larger iron to magnesium bulk compositional range. This pelite unit is similar in appearance to Myer Cave Formation pelites from the Green Bay area to the southwest (F.D. Ford, personal communication of unpublished data, 1992), but lacks staurolite, which breaks down by metamorphic reaction to form additional biotite-garnet-sillimanite. This staurolite-out isograd is located immediately southwest of the map area, running north to south, roughly through the centre of Mud Lake (F.D. Ford, personal communication of unpublished data, 1992). The pelite described above appears to be partly interbedded with the overlying unit, a biotite schist, similar in appearance to the previously described biotite schists.

A thin, laminated, biotite-diopside calc-silicate schist, assigned to the Fernleigh Formation, is the highest stratigraphic unit encountered. Thin alternating diopside-rich and biotite-rich layers (beds) characterize the unit. Metamorphic reaction has produced the diopside-rich layers from carbonate-rich layers, present in lower grade equivalents (Moore and Thompson 1980). A second type of calc-silicate schist appears to overlie the typical Fernleigh Formation schists. This rock is more massive with irregularly spaced calc-silicate bands instead of well-developed laminations.

On the southern limb of the Fernleigh structure, a clast-supported conglomerate of the Bishop Corners Formation appears to be in direct contact beneath the Fernleigh Formation, implying that the Myer Cave Formation is absent. The conglomerate is clast-supported and monomictic, composed mainly of vein quartz pebble, with a micaceous matrix. This conglomerate is readily distinguished from an underlying conglomerate, and although relatively thin, appears to have a strike-length of at least 8 km. It should be noted that the Myer Cave Formation units, absent from the southern limb of the Fernleigh belt near Frontenac County road 509, appear to be present north of Sunday Lake, where siltstone, iron-rich pelite and calcite marble are found between the Fernleigh Formation and Bishop Corners Formation quartz-pebble conglomerate. In the Frontenac County road 509 area, the lowermost Flinton Group unit on the southern limb of the Fernleigh belt is a matrix-supported, polymictic conglomerate with a mafic matrix, similar to conglomerate of the Ompah Formation (*see* "Flinton Group", "Stratigraphy", "Ompah Formation").

Ompah Structure

Despite the large amount of mapping within the Ompah structure, only 3 previous workers—Miller and Knight (1914), Moore and Thompson (1972, 1980) and Pauk (1983, 1987)—recognized the presence of an unconformity at the base of the "Ompah Conglomerate" and attempted to interpret the structure by assigning units above the unconformity to the Flinton Group. Due to the reconnaissance scope of their project, Miller and Knight (1914) only distinguished the "Ompah Conglomerate", which they assigned to the "Hastings Series", from the surrounding Grenville Supergroup rocks, which they assigned to the "Grenville Series". Smith (1958) identified the "Ompah Conglomerate" as being "Hastings-type" and recognized that it, and that associated quartzite in the Ompah structure, rests on older marbles. Smith (1958, 1969) also recognized that rhythmically bedded schists, assigned by Moore and Thompson (1972, 1980) to the Fernleigh Formation, lay stratigraphically above the "Ompah Conglomerate" found at the base of the Fernleigh structure northeast of Mud Lake. Smith (1969) also identified the "Ompah Conglomerate" as the basal unit of the Ompah structure. He noted an isolated exposure of coarse conglomerate east of the Lavant post office (Frontenac County road 509 and Lanark County road 12 junction) where the conglomerate appears to rest on older marbles south of the syncline, but did not specifically identify this relationship as an unconformity.

Moore and Thompson (1972, 1980) assigned conglomerate and quartzite in the Ompah structure to the Bishop Corners Formation of the Flinton Group. These authors, in addition to others (Smith 1958; Pauk 1983), suggested that the fine-grained, laminated to massive, hornblende-biotite and hornblende schists on the east end of Sunday Lake lie stratigraphically above, and are, therefore, younger than the "Ompah Conglomerate". In contrast, Rivers (1976) stated that there was no direct evidence for an unconformity in the synoptic area, suggesting that if it were present, it was obscured by lack of outcrop and by parallelism of unit contacts imposed by several periods of coaxial deformation. Rivers (1976) also questioned the assignment by Moore and Thompson (1972) of conglomerate and pelitic units in the Ompah structure to the Flinton Group, noting that metavolcanic rocks occur in the Ompah structure, structurally and possibly stratigraphically above the Flinton Group, which, by definition, contains only metasedimentary rocks.

Correlation between the Ompah structure and the Fernleigh belt is based on the observation that conglomerate bands within the Ompah structure are lithologically identical to the conglomerate found at the base of the southern limb of the Fernleigh belt (Ford 1992). The similarity of the 2 conglomerates can be used to support the assignment of the Ompah structure conglomerates to the Flinton Group, as the conglomerate in the Fernleigh belt is clearly part of the Flinton Group. In addition to lithologic similarity, mapping by Ford (1992) indicated that the 2 structures are in direct contact northeast of the Ardoch road bridge over the Mississippi River. Diopside-bearing, rhythmically layered schists of the Fernleigh Formation are in sharp contact with Bishop Corners Formation clast-supported, quartz-pebble conglomerate with a micaceous matrix. This conglomerate is in sharp contact with Ompah-type conglomerate, which persists with good outcrop coverage for a kilometre to the southeast. Previous mapping by Moore and Thompson (1980) and Pauk (1983) indicated that the 2 structures ("synclines") were separated by a narrow anticline of pre-Flinton Group marble; however, in the area described above, there is insufficient room for a marble band to occur between the 2 structures (*see* Map P.3443).

Key to the understanding of the geology of the Ompah structure is the realization that the metavolcanic rocks, volcanic metasediments and dolomitic marbles that occur in the core of the structure near Sunday Lake must be correlative with the Grenville Supergroup, and are, therefore, older, not younger than the "Ompah Conglomerate". Several observations made by Ford (1992) support this conclusion.

1. Stromatolites in the dolomitic marble belt that runs through the centre of Sunday Lake (*see* Photo 10) indicate an affinity with the Grenville Supergroup. As noted by Easton (1992c), stromatolites are common in this belt of dolomitic marbles that can be traced from Sunday Lake to Lavant Long Lake. Whereas stromatolites are relatively common in the Grenville Supergroup, only 1 occurrence of stromatolites in Flinton Group marbles has been documented to date (Bright 1986; Easton 1992c). The apparent rarity of stromatolites in the Flinton Group, combined with the presence of Grenville Supergroup stromatolitic marbles to the north and the west, suggests that it is most reasonable to assign the Sunday Lake dolomitic marbles to the Grenville Supergroup.
2. The suggestion by Moore and Thompson (1972) and Pauk (1983) that mafic rocks at the east end of Sunday Lake be assigned to the Flinton Group must be rejected. Although some of these rocks are clearly sedimentary, being quartz-rich and thinly laminated, probably mafic turbidites, others are more massive and finer grained, with less quartz and more hornblende and plagioclase, suggesting a mafic volcanic origin. It is unlikely that these mafic metavolcanic rocks belong to the Flinton Group as there has been no previous discovery of Flinton Group volcanic rocks.
3. Although some of the mafic turbidites are laminated and, therefore, grossly similar to the Fernleigh Formation in appearance, they lack the carbonate or diopside-rich interbeds of this formation. To assign these mafic turbidites to the Flinton Group would require the creation of a new, separate unit. Given the high degree of metamorphism in the area, such an assignment should be made only if there is irrefutable evidence that the rocks in question are Flinton Group in age. Since no such evidence exists, it seems more reasonable to assign this package of mafic metavolcanic and metasedimentary rocks to the Grenville Supergroup.

Previous authors have identified the Ompah structure as a northeast-plunging syncline. Mapping by Ford (1992) indicated that there were at least 2, possibly 3, periods of deformation and folding. The first period of deformation (D_1) produced northeast-trending, isoclinal, possibly recumbent folds. These first phase folds (F_1) are only evident from the map pattern. No distinctive structural fabric associated with F_1 was recognized by Ford (1992).

The second period of deformation (D_2) resulted in a second set of northeast-trending folds (F_2) coaxial with F_1 folds. F_2 folding produced the major anticlinal structure previously identified as the Ompah "syncline". The F_2 folds plunge to the southwest and are overturned to the north. A steeply dipping axial planar cleavage, striking approximately 045°, is well preserved. The intensity and preservation of D_2 fabrics, combined with the elimination of pre-existing D_1 fabrics, suggests that D_2 was the strongest deformation in the area. The realization that the Ompah anticline is a D_2 fold supports the suggestion, first made by Moore and Thompson (1980), that D_2 structures are restricted to areas of relatively high-grade metamorphism. Pebbles in the "Ompah Conglomerate" are deformed into prolate ellipsoids to produce an intense stretching lineation that plunges shallowly (5 to 15°) to the northeast and which has not yet been associated with any specific deformation event.

Northwest-trending F_3 folds have not been positively identified in the area; however, the map pattern suggests that F_1 and F_2 folds may, in some cases, be doubly plunging. The three-phase deformational history given above is in agreement with Thompson (1972), Rivers (1976) and Moore and Thompson (1980). Both Rivers (1976) and Moore and Thompson (1980) identify the Ompah "syncline" as a D_1, rather than a D_2 structure.

Mosque Lake Area

The presence of Flinton Group rocks in this area was first documented by Easton (1992c). The rocks are exposed southeast of Mosque Lake in a north-plunging, overturned synform at least 3 km long and 1 km wide at its widest point. The synform extends south into the Ardoch area; however, Pauk (1987) did not report any Flinton strata on strike with the synform. At least 2 formations of the Flinton Group are present southeast of Mosque Lake: kyanite-muscovite schists and micaceous meta-arenites of the Bishop Corners Formation (unit 21d), and garnet-sillimanite-biotite schists of the Myer Cave Formation (unit 22d). Garnet-hornblende schist of the Ore Chimney Formation (Grenville Supergroup) are also present, and may represent a regolith developed on adjacent garnetiferous gabbroic rocks. All 3 formations are tightly infolded, and a repeated stratigraphic sequence was not evident within the synform at the 1:10 000 mapping scale used by Easton, Ford and Cooke (1995). The synform is associated with intermediate gneisses, possibly representing recrystallized mylonites of the Shabomeka shear zone. Easton and Ford (1991) have previously noted an association between the early shear zones and occurrences of the Flinton Group.

CORRELATION ISSUES

The discontinuous distribution of the Flinton Group across the synoptic area hinders correlation between the different outcrop areas and belts. This is especially true with respect to the metaconglomerate and meta-arenite units within the Flinton Group. Two stratigraphic approaches are possible. One would be to include all of the conglomerate-arenite units within one formational unit, either as one broadly defined stratigraphic unit or as members within a formation; for example, the Bishop Corners Formation. The other would be to define formations for each geographically distinct conglomerate-arenite package, and then to correlate these units with one another, if possible. The latter approach has been taken in this report. Thus, there are 3 conglomerate-arenite units in the synoptic area (Norway Lake, Ompah and Bishop Corners formations) and 1 unit outside the area (Kaladar Formation). All of these units are mappable at 1:50 000 scale and, thus, meet this criterion for definition as formations.

The rationale for taking this approach was that there seemed to be enough subtle lithologic and geochemical variation, as well as relative age relationships, between the different conglomerate-arenite packages that it seemed unlikely that they were all deposited synchronously or near synchronously as one unit. In particular, as discussed in "Flinton Group" "Geochemistry of the Flinton Group", it is possible that the Ompah and Kaladar formations may be related to each other, because of their calcareous matrices. Furthermore, they may be older than the Bishop Corners Formation. On the basis of clast composition, the Norway Lake, Ompah and Kaladar formation metaconglomerates are all polymict, whereas the Bishop Corners Formation metaconglomerate is monomict. This could suggest both a different environment, and time, of deposition. On the basis of these uncertainties, it seemed best to treat these conglomerate-arenite units as separate stratigraphic units.

ORE CHIMNEY FORMATION (PRE-FLINTON PALEOREGOLITH)

Moore and Thompson (1980), Harnois (1988a) and Harnois and Moore (1988) suggested that a paleoregolith, now represented by a black weathering, biotite-garnet ± staurolite ± hornblende schist was developed on the Grenville basement prior to Flinton Group deposition. By definition, this unit is transitional with the immediately underlying rock strata, and is only preserved locally along the unconformity that marks the basal Flinton Group. Consequently, it is not shown as a mappable unit on Map P.3443. Also, as defined by Moore and Thompson (1980), the Ore Chimney Formation is part of the Grenville Supergroup, not the Flinton Group. However, it is discussed in this section of the report because of its genetic and spatial linkage to the Flinton Group.

Localities where schist of the Ore Chimney Formation is observed are generally found in mafic metavolcanic units in areas of complex structure. Consequently, some authors (e.g., Springer 1982; Dillon 1985; Laing, Duke and Johnson 1987) have argued for a structural or alteration origin for rocks of the Ore Chimney Formation. In contrast, Harnois and Moore (1988) suggested that the regolith developed *in situ* because their geochemical studies showed a strong correlation between the bulk composition of the adjacent basement rocks and the adjacent Ore Chimney Formation, a correlation which would not be expected if the unit formed as the result of alteration and deformation. Harnois and Moore (1988) suggested that some subsequent, local, sedimentary reworking of the regolith has occurred, and they do not deny that locally, later structural modifications have occurred.

As part of this study, 2 additional areas where the Ore Chimney Formation is preserved were identified. The first, and most convincing area, is located southwest of Marble Lake, and is illustrated in Figure 13. Although shown on the map of the Marble Lake area by Moore and Morton (1986), this locality was not described by them. As shown in Figure 13, at this locality, a chlorite-garnet schist

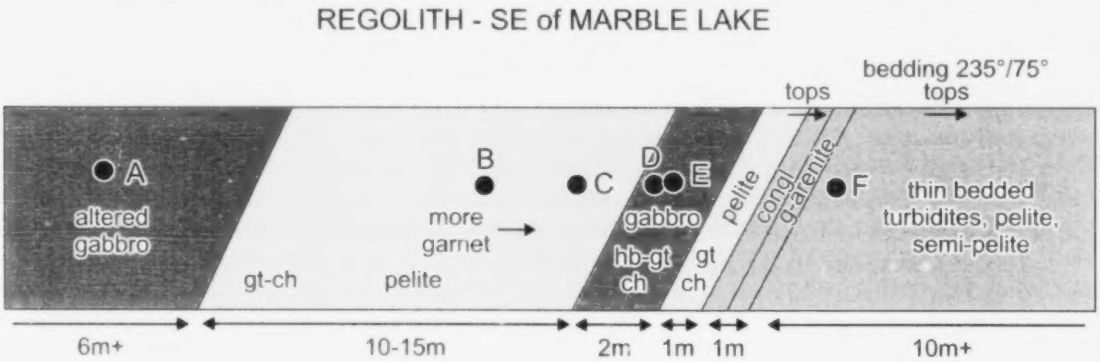

Figure 13. Schematic diagram through the Ore Chimney Formation west of Marble Lake, showing transition from underlying basement rocks (left) to overlying Bishop Corners Formation metapelitic rocks (right). Photo 34 is from point A; Photo 35 is from the area between points E and F.

horizon, locally containing blocks of altered, coarse-grained mafic rocks, lies structurally above a pillowed flow containing coarse secondary amphibole crystals that give the rock a pseudo-gabbroic texture. These pillowed flows are relatively fresh 15 m to the west of the chlorite-garnet schist, and become progressively altered nearer the contact. Alteration consists of hematization and sericitization of feldspars, and alteration of hornblende to chlorite. No shearing is apparent in the pillowed flows as the contact is neared. The chlorite-garnet schist is overlain by pebbly conglomerate, metawacke, and metaturbidites of the Bishop Corners Formation. Contact between the chlorite-garnet schist and the lowermost conglomerate bed is sharp. No evidence of shearing along this contact was observed.

The other locality is in the Mosque Lake belt, but complex fold interference patterns in the area, and higher metamorphic grade, make recognition of the Ore Chimney Formation more difficult. Here, the Flinton Group rocks overlie a medium-grained gabbro, which locally develops metamorphic garnet near the margins of the body and near the Flinton Group contact. The gabbro is locally overlain by a banded gneiss, containing large garnet porphyroblasts and consisting of alternating bands of fine-grained green-black amphibole and white plagioclase. This banded gneiss most likely represents the Ore Chimney Formation, and is only located between the basal Flinton Group units and the underlying gabbro. This locality was not sampled for geochemical study.

NORWAY LAKE FORMATION (UNIT 19)

South of Sand Lake, the Norway Lake granite is rimmed by a granite boulder cobble metaconglomerate correlated with the Flinton Group (herein, and Moore and Thompson 1980). Smith (1958) originally described the contact as an unconformity, but subsequently (Smith, Vogel and Spence 1969) described the contact as intrusive, in part because modal analyses of granite cobbles showed the cobbles contained less microcline than the granite. Figure 14 illustrates the geological relationships noted by Smith, Vogel and Spence (1969). The subangular to subround cobbles decrease in size away from the granite (Cooke 1992; Figure 15), and the distribution of pelitic and arkosic facies intercalated with the conglomerate horizons is consistent with the granite cobbles being derived locally from the granite (*see* Figure 15). The modal data of Smith, Vogel and Spence (1969) most likely reflect preferential weathering of potassium feldspar in the granite prior to and during deposition of the cobbles. Alternatively, Ayer (1979) reported the presence of both granite and albite trondhjemite within the Abinger Granite, and the Norway Lake granite shows a similar compositional range. Thus, the microcline-poor samples described by Smith, Vogel and Spence (1969) may simply be cobbles transported from other parts of the Norway Lake, or the adjacent Abinger, granites.

Field party personnel, in remapping this area (*see* Figure 15), found that the metaconglomerate was interbedded with feldspathic metalitharenites and meta-arenites as well as metapelites containing microcline and garnet porphyroblasts and sillimanite. Kyanite is also present at scattered localities in these rocks. These additional lithologies are similar to Flinton Group metapelites from classic Flinton Group lithologies (Bishop Corners pelite and arenite), and further support the correlation of the metaconglomerate with the Flinton Group. In addition to this previously described locality, several other metaconglomerate and metapelite horizons occur along the length of the Norway Lake granite in the Mazinaw area (*see* Map P.3443). All metaconglomerate horizons show similar relationships to the granite, and they all contain varied amounts of granite boulder metaconglomerate, feldspathic metalitharenite and metapelites. These clastic rocks are discordant with respect to underlying rocks, generally tectonized equivalents of the Mazinaw Lake Formation along the Shabomeka and Swamp Lake shear zones, which wrap around the Norway Lake granite. On the basis of lithology and geochemistry, the metaconglomerate and metapelitic units proximal to the Norway Lake granite are correlated with conglomerates of the Ompah and Kaladar formations (*see* subsequent sections "Geochemistry of the Flinton Group" and "Provenance of the Flinton Group").

OMPAH FORMATION (UNIT 20)

The Ompah Formation consists of 2 rock types: matrix-supported metaconglomerate and feldspathic meta-arenite. Metaconglomerate of the Ompah Formation occurs in both the Fernleigh and Ompah structures (Ford 1992).

Matrix-supported conglomerate with an amphibole and biotite-rich matrix (*see* Photo 30) of the Ompah Formation forms the basal unit of the southern limb of the Fernleigh belt in the Ompah–Sunday Lake area. The conglomerate contains a wide variety of clasts, in order of abundance they are 1) fine-grained granodiorite to tonalite, 2) quartzite, 3) vein quartz, 4) medium-grained granite, 5) mafic clasts (now composed mostly of biotite), and 6) rare, pink, calcite marble clasts. Clast size varies from 1 to 30 cm.

The matrix of this conglomerate is unusually rich in amphibole and biotite. In thin section, the matrix is composed predominantly of granoblastic quartz and plagioclase and pleochroic green amphibole. Minor phases include epidote, opaque minerals, carbonate and titanite. A small amount of plagioclase has been altered to sericite and texturally late, radiating chlorite crystals overgrow earlier amphiboles. Garnet was observed in the matrix at several outcrops. The matrix amphibole may have grown as the result of a carbonate breakdown reaction that consumes calcite and produces calcic amphibole. This suggestion is supported by the decreasing proportion of marble clasts in the conglomerate as one moves up metamorphic grade to the northeast.

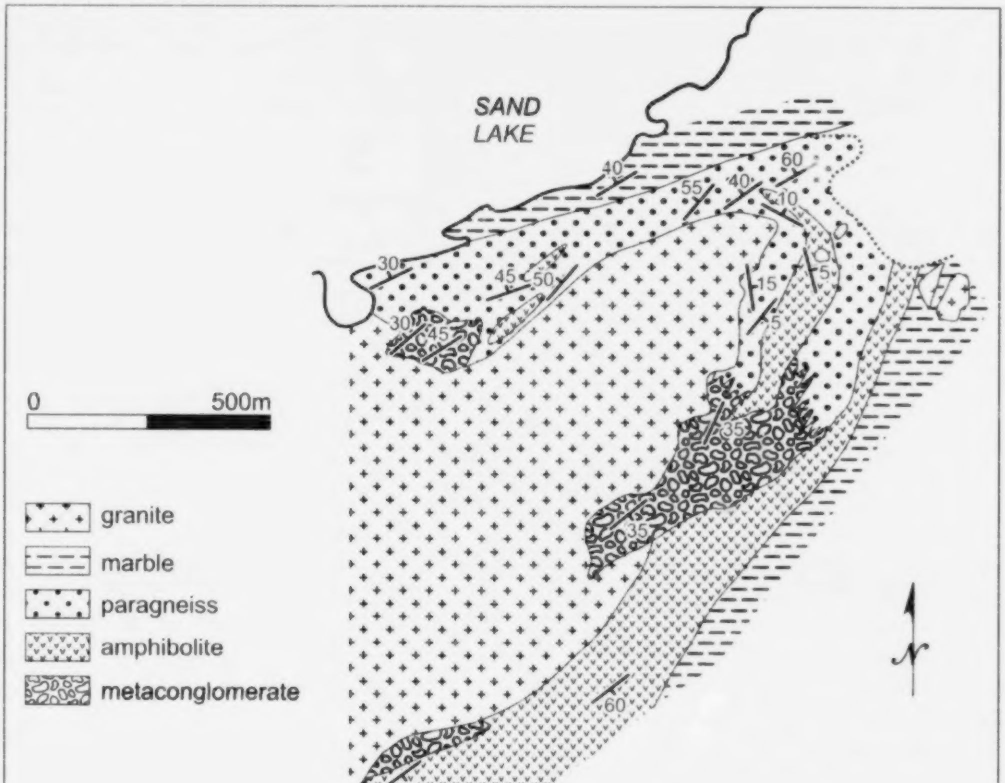

Figure 14. Geology of the Sand Lake area, showing the distribution of metaconglomerate (*after* Smith, Vogel and Spence 1969).

An amphibole-biotite rock resembling the matrix of the Ompah Formation conglomerate, but lacking pebbles, was observed at several locations by field party personnel (Easton, Ford and Cooke 1995). This unit may have originally been a calcareous mud.

On the north shore of the peninsula in Grindstone Lake, field party personnel found a spectacular outcrop of matrix-supported, granite cobble conglomerate with a coarse biotite-diopside-calcite matrix. The granite cobbles are angular to subrounded and range from 2 to 3 cm long to angular blocks up to 40 cm across. The fine-grained granite cobbles closely resemble the granite present in a small intrusion 200 m to the southeast. Although differing in matrix composition, this conglomerate resembles Flinton Group conglomerates present around the margin of the Norway Lake granite (Mazinaw area, Easton and Ford 1991) in both clast type and geologic setting. About 500 m east of Grindstone Lake is an outcrop of biotite-garnet-(sillimanite?) schist, similar to Flinton Group strata in the Mosque Lake area. This outcrop

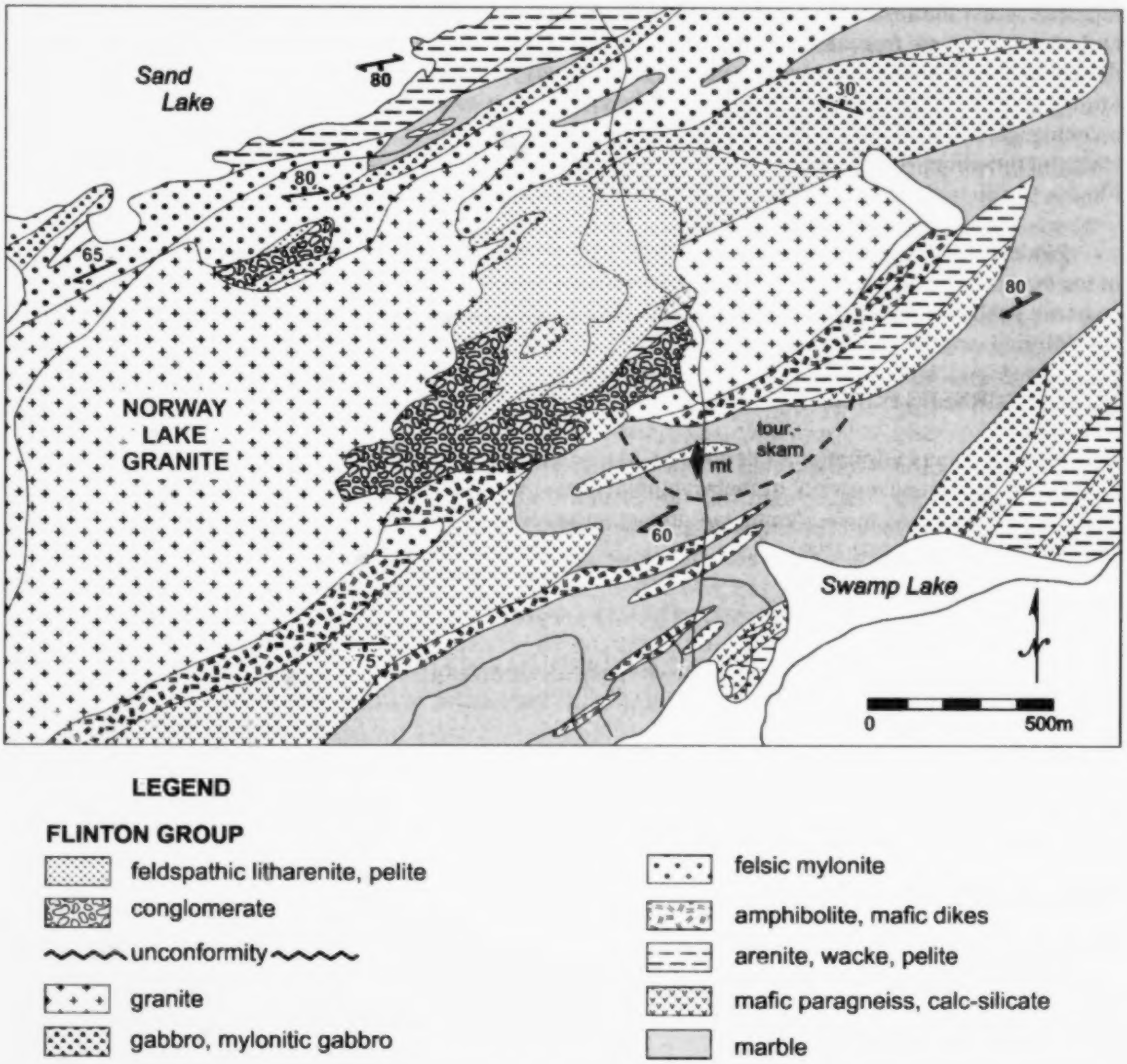
Sand Lake
80
30
80
65
80
NORWAY LAKE GRANITE
tour.-skarn
mt
60
Swamp Lake
75
0
500m
LEGEND
FLINTON GROUP
feldspathic litharenite, pelite
conglomerate
unconformity
granite
gabbro, mylonitic gabbro
felsic mylonite
amphibolite, mafic dikes
arenite, wacke, pelite
mafic paragneiss, calc-silicate
marble

Figure 15. Geology of the Sand Lake area, showing the distribution of metaconglomerate, based on the results of this study.

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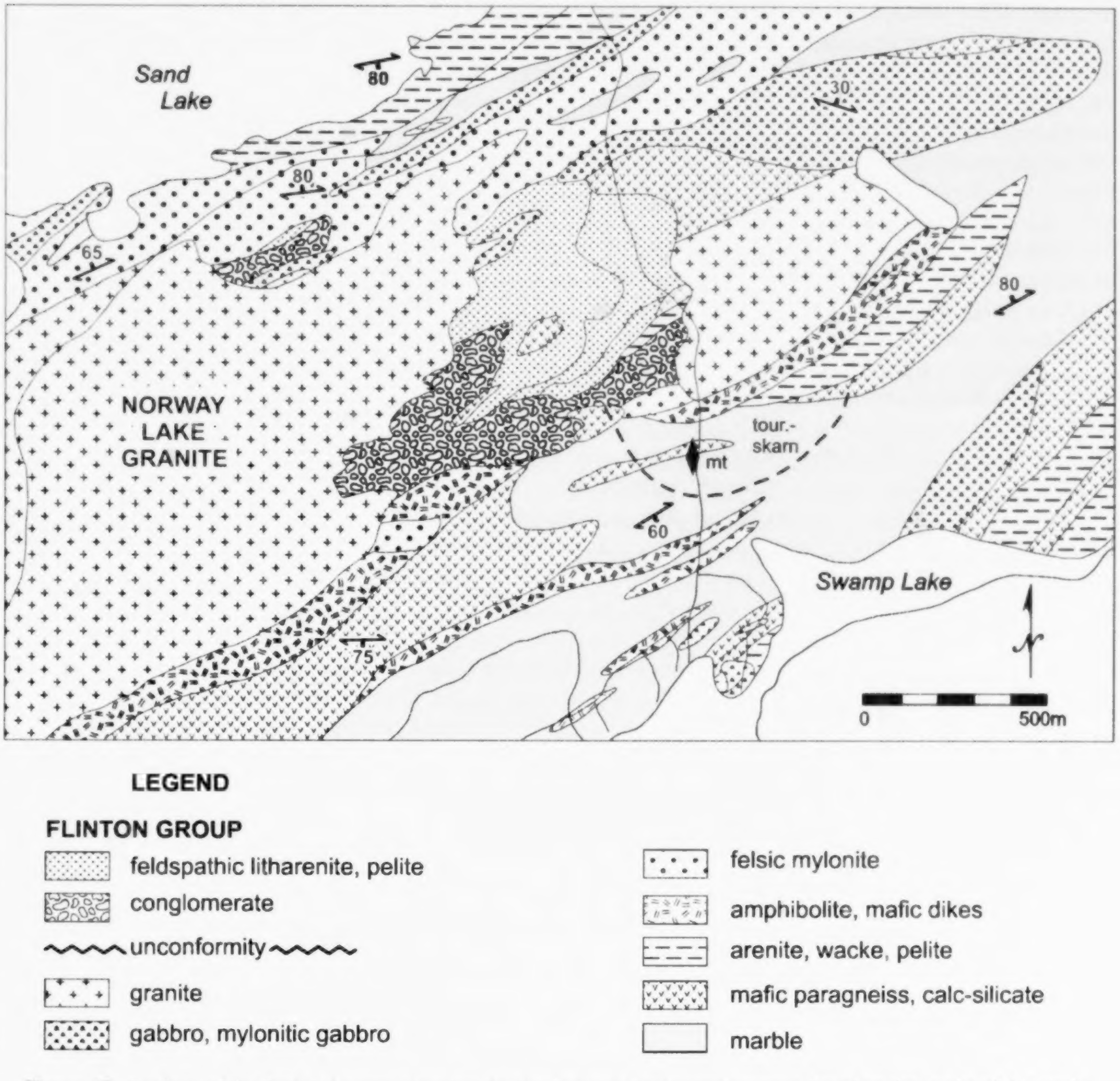
Sand Lake
80
30
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80
NORWAY LAKE GRANITE
tour.-skarn
mt
60
Swamp Lake
75
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500m
LEGEND
FLINTON GROUP
feldspathic litharenite, pelite
conglomerate
unconformity
granite
gabbro, mylonitic gabbro
felsic mylonite
amphibolite, mafic dikes
arenite, wacke, pelite
mafic paragneiss, calc-silicate
marble

Figure 15. Geology of the Sand Lake area, showing the distribution of metaconglomerate, based on the results of this study.

along the east flank of the granite body along which the conglomerate is found. Thick till cover in the Grindstone Lake area may cover additional Flinton Group outcrops. This conglomerate is tentatively assigned to the Ompah Formation, in part because of its calcareous matrix.

Feldspathic meta-arenite, termed quartzite by previous workers, lies above the Ompah Formation conglomerate. Facing directions based on cross-bedding found in 2 locations confirms that the feldspathic meta-arenite lies stratigraphically above metaconglomerate of the Ompah Formation (Ford 1992). The feldspathic meta-arenite weathers buff-white and is fine grained. Bedding style is varied; some outcrops contain abundant 1 cm thick beds, whereas other outcrops are massive. The arenite is similar in appearance to the Myer Cave Formation arenite found in the Fernleigh belt.

It is not possible to tell if metaconglomerate of the Ompah Formation on the south limb of the Fernleigh structure is older than the muscovite pelite on the north limb because stratigraphy is not repeated across the structure. The map pattern, however, suggests that foliation and layering within the Ompah structure are truncated by the Fernleigh belt. Rivers (1976) stated that this truncation was due to the structural attenuation of certain units causing convergence of contacts; however, where observed by Ford (1992), this truncation appeared to be a stratigraphic, not a structural phenomenon, because there is no evidence of a structural discontinuity between Fernleigh belt rocks and metaconglomerate of the Ompah Formation. This suggests that the Ompah Formation metaconglomerate may be older than other Flinton Group rocks in the Fernleigh belt.

Evidence that metaconglomerate units within the Flinton Group are diachronous is also found south of the synoptic area near Kaladar. There, the Kaladar conglomerate of the Flinton Group contains quartzite pebbles similar in appearance to underlying Flinton Group quartzites, implying that the quartzite was lithified, eroded and transported prior to Kaladar conglomerate deposition.

BISHOP CORNERS FORMATION (UNIT 21)

The Bishop Corners Formation as defined by Moore and Thompson (1980) consists of metapelite, metaquartzarenite and a variety of metaconglomerates. Although generally thought of as a metaconglomerate and meta-arenite unit, in fact, metapelites constitute the majority of the Bishop Corners Formation in the synoptic area.

Arenite-Conglomerate Member

This unit is not well represented in the map area (units 21a and 21b), but is abundant in the Fernleigh belt immediately south of the map area, where it is described in detail by Moore and Morton (1986). The base of the member consists of light grey or white, fine-grained metaquartzarenite, with accessory muscovite, kyanite, hematite and tourmaline. Cross-bedding is common in the quartzite and, although current direction is difficult to ascertain due to deformation, tops are distinct. The metaquartzarenite is overlain by a clast-supported conglomerate, which consists of well-rounded and well-sorted pebbles and cobbles of metaquartzarenite in a micaceous quartz matrix.

Pelite Member

Within the Fernleigh belt, grey, micaceous pelitic schist (unit 21c) with a quartz-muscovite-hematite matrix containing porphyroblasts of biotite, kyanite, microcline or chloritoid predominates. North of Marble Lake, Bishop Corners Formation pelitic schist is only found on the north flank of the Fernleigh belt. The major effect of increasing metamorphic grade on this unit as one goes from southwest to northeast across the synoptic area is an increase in grain size, particularly in the micas (unit 21d). In addition, to the northeast, in thin section, kyanite porphyroblasts are increasingly pseudomorphed by sillimanite.

MYER CAVE FORMATION (UNIT 22)

F.D. Ford (personal communications, 1990 and 1991) has proposed that the Myer Cave Formation can be divided into 5 members within the synoptic area (*see* Table 4; *see* Figure 12). From oldest to youngest, these newly defined members are

1. a Pelite member consisting of homogeneous, graphitic, staurolite + (chloritoid at lower grade) + garnet + biotite pelite
2. a Laminated Schist member consisting of finely laminated, graphitic schists with pyrite laminae. A thin (3 to 15 m thick) dolomitic marble horizon is present at the base of this member.
3. a Calcareous member consisting of fetid, thinly bedded, calcitic marbles interbedded with finely laminated, graphitic schists. Relatively schist-free horizons, 10 to 50 m thick, of calcitic marbles are present within this member.
4. an Unlaminated Schist member consisting of poorly to unbedded graphitic schist containing disseminated pyrite stringers. The Unlaminated Schist member grades into the Fernleigh Formation over a distance of about 15 m.
5. a Megabreccia member, found only in the Myers Cave to Green Bay area containing blocks (0.3 to 10 m in length, 0.2 to 5 m in width) of dolomitic and calcitic marble derived from the Grenville Supergroup, and thinly bedded calcite marble blocks derived from the Carbonate member with either a graphitic pelite matrix similar in composition to the pelite member or a calcareous matrix. This megabreccia is a primary depositional feature, and is not the result of later tectonism.

Figure 12 summarizes the possible facies relationships between these various members in the Mazinaw area. As discussed in greater detail in "Geochemistry of the Flinton Group", the unlaminated schist member is geochemically similar to the overlying Fernleigh Formation, consistent with field observations and the stratigraphy outlined above.

These members were originally defined for the Fernleigh belt in the Cloyne to Ardoch area, but the members can be recognized at higher metamorphic grades in the Palmerston Lake area, particularly the pelite, laminated schist and carbonate members. In addition, locally within the Palmerston Lake area, an arenite member is observed, consisting of semi-pelitic to psammitic schists. This unit does not seem to be extensive enough to warrant definition as a formal stratigraphic unit, but is locally present and is separated out on the Palmerston Lake map (Easton, Ford and Cooke 1995).

The lowermost unit of the Myer Cave Formation is an iron-rich pelite that conformably overlies aluminous pelites of the Bishop Corners Formation. East of Mississagagon Lake, the 2 pelites are readily distinguished by their metamorphic mineral assemblages, with biotite-garnet-staurolite dominant in the Myer Cave Formation pelite and kyanite-plagioclase-muscovite dominant within the Bishop Corners Formation. East of Mississagagon Lake, pelite of the Bishop Corners Formation directly overlies Grenville Supergroup marbles and siliceous clastic metasedimentary rocks. Combined thickness of both pelites units is about 50 to 75m, split equally between both stratigraphic units.

The pelite member is overlain by a thin, 2 to 10 m thick, unit of dolomitic marble, that is variably sheared and recrystallized, particularly along the north shore of Mississagagon Lake. Several gold occurrences, most notably the Hardie occurrence (Barron 1983), are associated with this horizon, as are sphalerite, galena and sulphosalt occurrences (e.g., Barrie Syndicate and Mazinaw Base Metals occurrences).

Above the pelite member is the laminated schist member, which consists of grey to black weathering, graphitic sulphidic (pyrite-pyrrhotite-chalcopyrite) finely laminated schist (*see* Photo 21).

This unit is thickest in the Myers Cave–Green Bay area, and becomes thinner to the northeast where it is overlain by the unlaminated schist member (*see* Photo 22). Total thickness of these 2 members is difficult to estimate, but it is on the order of 200 m.

A distinctive 30 to 50 m thick, thin- to medium-bedded calcite marble (*see* Photo 23) occurs in the Fernleigh to Ardoch and the Ompah to Canonto areas. The carbonate member is intercalated with the upper part of the unlaminated schist member. It lies near, but does not mark the contact between the Myer Cave and Fernleigh formations. Stromatolites have not been reported from the Myer Cave Formation within the synoptic area, although Bright (1986) reports stromatolites from the Flinton Group in the Clare River area.

In the Myers Cave–Green Bay area, the carbonate member is absent and, instead, a carbonate clast megabreccia unit is present (*see* Photo 24). Clast size is quite variable (*see* Photos 24 and 26), ranging from a few centimetres in size to large, angular blocks 30 to 50 m in length. The unit is best exposed in roadcuts along Frontenac County road 506. Near Myers Cave, the matrix to the unit is dominantly calcareous, whereas in the Green Bay area, the matrix consists of graphitic schist. It is unclear at Green Bay whether or not the unit incorporates blocks of the pelite member, or rests unconformably on an irregular surface developed on the pelite member. Two types of carbonate clasts occur in the unit, grey to blue, massive, medium-grained, slightly sheared, calcite and dolomite marble clasts, and brown-grey weathering, calcite marble which is little recrystallized and shows excellent preservation of textures (compare Photos 25 and 26). The more massive fragments resemble Grenville Supergroup marbles in the area in terms of texture and appearance and, as discussed subsequently under "Geochemistry of the Flinton Group", are geochemically indistinguishable from Grenville Supergroup dolomitic marble. One explanation for the difference in preservation is that the unit includes Grenville Supergroup clasts that had been subjected to a pre-Flinton metamorphic episode, and clasts derived from the calcareous member of the Myer Cave Formation. An alternative explanation is that metamorphism of the megabreccia was varied, perhaps with graphite in the matrix poisoning metamorphic reactions. This latter explanation does not account for the absence of reaction rims along the clasts, the occurrence of clasts side by side, the presence of similar-type clasts in the megabreccia with a calcareous matrix, or the geochemical similarity with Grenville Supergroup rocks. Pelite blocks within the unit contain biotite and staurolite, suggesting that metamorphic grade within the megabreccia mirrors the regional metamorphic grade (unless the pelite represents clasts metamorphosed prior to Myer Cave Formation deposition).

The stratigraphic setting of the megabreccia is unclear. It appears to represent a mixture of laminated and unlaminated schist, pelite, and carbonate. The megabreccia samples most of the Flinton Group section between the Bishop Corners and Fernleigh formations. As a consequence, it appears to be dominantly intraformational, and probably formed as the result of syndepositional tectonic movement on a carbonate slope, perhaps analogous to the Cow Head Group breccias in the Paleozoic of western Newfoundland (James et al. 1988), although the depositional settings of the Flinton Group carbonates and the Cow Head Group breccias may be vastly different.

An additional member may be present within the Myer Cave Formation in the northeastern part of the map area. Ford (1992) assigned to the Myer Cave Formation a fine-grained, homogeneous, pink-weathering, metasandstone (feldspathic arenite) present in the Fernleigh belt in the vicinity of Sunday Lake. This unit is interbedded with a more biotite-rich lithic wacke that commonly contains garnet. The metasandstone is distinguished from Bishop Corners Formation quartzites by composition and by a lack of primary bedding structures, such as heavy mineral-rich cross-beds. A similar rock was described by Moore and Thompson (1980) as the micaceous quartzofeldspathic psammite member of the Bishop Corners Formation.

FERNLEIGH FORMATION (UNIT 23)

The Fernleigh Formation (biotite-carbonate schist of Smith (1956)) stretches from 4 km west of Fernleigh northeastward to Ompah and the Sunday Lake area (Pauk 1983, 1987), although it does not crop out continuously over this distance. In the Marble Lake to Ardoch area, Pauk (1987) and Smith (1956) showed the unit ending 2 km west of Fernleigh. Field party personnel were able to trace the formation an additional 2 km to the west. Moore and Thompson (1980) defined the reference section for the Fernleigh Formation at UTM 344000E 4974300N, east of Fernleigh along a power line access road. New roadcuts subsequent to their study suggests a more appropriate and better exposed reference section along Frontenac County road 506 east of Fernleigh at UTM 345200E 4974700N.

Moore and Thompson (1980) describe the contact with the underlying Myer Cave Formation as abrupt; however field party personnel noted that locally there is a transition zone, 3 to 10 m thick, between unlaminated sulphidic schists of the Myer Cave Formation and thin-bedded dark grey and grey-brown calcareous pelites of the Fernleigh Formation, where the 2 rock types are interbedded (*see* Photo 27). The transition zone has also been noted geochemically (*see* "Geochemistry of the Flinton Group"), with rocks from this transition zone, as well as from the unlaminated schist member of the upper Myer Cave Formation being geochemically indistinguishable from the Fernleigh Formation schists.

The Fernleigh Formation is one of the most homogeneous of the Flinton Group formations, consisting of dark brown to rusty brown weathering, fine-grained, thin-bedded, slightly schistose calcareous pelites. Photo 28 illustrates bedding within typical Fernleigh Formation pelites. Some layers are graded, with carbonate-rich tops containing convolute laminae. Some pyritic and calcareous layers are recessive weathering. The top of the Fernleigh Formation is not exposed; however, the unit has a minimum thickness of 250 to 300 m. Toward Ardoch, the formation is locally highly schistose, with numerous minor folds. These areas of more intense deformation coincide with the traces of north-northwest-trending faults in the area; consequently, it is likely that these minor folds are not related to any regional deformational event affecting the Fernleigh Formation. Within the map area, and eastward toward Ardoch, the only metamorphic porphyroblasts present in the Fernleigh Formation are greenish tremolite-microcline or microcline clots (*see* Photos 28 and 32).

Geochemistry of the Flinton Group

INTRODUCTION

The geochemistry of the Flinton Group was studied with 3 goals in mind. First, to determine if geochemistry might aid in discriminating between Grenville Supergroup and Flinton Group rocks, which would be particularly useful in areas of high metamorphic grade and where transposition of fabrics within the metasedimentary rocks has occurred. Second, to use geochemistry as an aid in characterizing provenance of the Flinton Group and, as a consequence, to assist in unravelling the depositional history of the Flinton Group. Third, to better evaluate the mineral potential of the Flinton Group, through characterization of its geochemistry.

As outlined below, all of these goals were realized, even though the geochemistry of the Flinton Group is quite complex. The bulk of the samples collected from this study are from the Fernleigh belt, in the Myer Cave to Ardoch area and from Ompah to Clyde Forks. The samples collected in the course of this study were supplemented with 10 major element analyses of Flinton Group metapelites from the Myer Cave to Fernleigh area (Hounslow and Moore 1967) and 4 analyses of metaconglomeratic rocks from the Norway Lake area from Cooke (1992). Comparative samples from the Harlowe area and the Ore Chimney Mine, and from the Kaladar conglomerate, come from Harnois and Moore (1988) and van de Kamp (1971), respectively. Collectively, roughly 70 samples of Flinton Group rocks were available for study.

Each of the Flinton Group formations are geochemically distinct. Some of these differences can be attributed to provenance, whereas others are depositional or postdepositional in origin. These differences are discussed below.

BORON

Previous workers have noted an abundance of tourmaline within the Bishop Corners Formation (Thompson 1972; Rivers 1976; Easton 1988). Consequently, the boron content of the Flinton Group and adjacent rock units was investigated to determine if boron, hosted in tourmaline, might be a useful discriminant in recognizing Flinton Group strata. Boron data were only available from the roughly 35 complete Flinton Group samples collected in this study, plus another roughly 35 partial analyses of both Flinton Group and Grenville Supergroup metasediments collected as a test group in the early phases of this study (*see* Appendix 1); thus, the results are only applicable to the Fernleigh belt.

The highest boron values occur within the Bishop Corners Formation (162 to 227 ppm), with lower values recorded from the Myer Cave Formation pelites (92 to 162 at lower grade, 33 to 92 at higher grades), with similar values from the Fernleigh Formation (93 to 162). These values are all generally higher than normal supracrustal and metaplutonic rocks of the Grenville Supergroup and its intrusive phases, although notable exceptions occur. Boron contents of Flinton Group carbonates are generally low (5 to 15 ppm) and are generally indistinguishable from Grenville Supergroup carbonates.

A ternary diagram of boron–vanadium–Al_2O_3 provides another perspective on the boron data. Vanadium provides an indication of iron and transition metal content of the rock, and Al_2O_3 provides an indication of either the pelitic character of the rock in terms of schists or non-carbonate component in the case of marbles. Several patterns can be discerned from this diagram (not shown). Flinton Group samples cluster near the centre of the diagram, with a distinct trend toward the vanadium apex for the Myer Cave Formation samples (possibly reflecting vanadium enrichment related to formation of the black shales making up much of this formation). A second trend of decreasing boron with increasing grade is seen within Myer Cave Formation samples from the Ompah area. Flinton Group calcitic marbles have higher boron and vanadium contents than do Grenville Supergroup carbonates. Non-Flinton metasedimentary and metaplutonic rocks generally have higher Al_2O_3 relative to boron and vanadium than do the Flinton Group rocks. Some Grenville Supergroup dolomites near the Flinton Group have elevated boron contents, and plot in 2 distinct fields: one near the lower grade samples lying near the boron apex; the other, at higher grades, is shifted toward the vanadium apex. The moderate boron enrichment in some Grenville Supergroup dolomites may be the result of 1) dolomitization related to diagenesis of the Flinton Group; 2) post-evaporite deposition of the lower Flinton Group and underlying strata, perhaps in conjunction with (1); or 3) remobilization of boron and local dolomitization of the Grenville Supergroup related to mineralizing fluids channelled along the Flinton unconformity.

It will be noted subsequently that barium and strontium are key elements in distinguishing Flinton Group versus Grenville Supergroup carbonates. On a barium–strontium–boron*10 diagram, most Flinton Group metapelites plot near the boron apex. The high-grade Myer Cave Formation samples plot toward the barium apex, suggesting some boron depletion. With the exception of the Sunday Lake metavolcanics, which are boron rich and barium poor, the Flinton metapelite samples plot in a distinct field on the barium–strontium–boron diagram. Although more data need to be collected, plots of boron–vanadium–Al_2O_3 and barium–strontium–boron*10 may be useful in discriminating lower grade Flinton Group rocks and potentially mineralized Grenville Supergroup carbonates from Grenville Supergroup strata.

It is informative to speculate on where boron might be hosted in the various units. Within the Bishop Corners Formation metapelites, as noted previously, there is petrographic evidence for abundant tourmaline in these rocks. In addition, within the Bishop Corners Formation, there is no indication of boron depletion with increasing metamorphic grade. In contrast, within the Myer Cave Formation metapelites, the data suggest that boron is driven off at higher-metamorphic grades, possibly related to decarbonation. This may indicate that within the Myer Cave Formation metapelites, boron is held mostly in phyllosilicates, with the consequence that boron is loosely held and susceptible to loss during recrystallization during prograde metamorphism. If this is the case, boron is likely to be only useful as a discriminant of all Flinton Group samples at upper greenschist to middle amphibolite facies (although it may still be useful for Bishop Corners Formation metapelites at higher metamorphic grades, as tourmaline binds boron more tightly). The loss of boron from the Myer Cave Formation schists, in conjunction with CO_2 loss (as discussed previously), at higher grade may be significant with respect to mineral potential evaluation, as other metals may also be lost from the system during these dehydration-decarbonation reactions.

ORE CHIMNEY FORMATION

Harnois and Moore (1988) studied the Ore Chimney Formation at 4 locales: the Addington Mine near Flinton, the Ore Chimney Mine, a section near Harlowe, and a section at Reid Lakes; all but the Addington Mine section lie within the synoptic area. Harnois and Moore (1988) noted similar geochemistry between the underlying rocks and the Ore Chimney Formation at the first 3 sites, particularly in REE patterns, which they attributed as an indication of derivation from the underlying host rock. They interpreted the Ore Chimney Formation as a paleosol; locally, sedimentary reworking of the uppermost part of the paleosol occurred prior to Flinton Group deposition. The paleosol interpretation has been questioned at both the Ore Chimney Mine and the Addington Mine, because of intense deformation and alteration in the host rocks. Alternatively, it has been suggested that the Ore Chimney Formation represents a hydrothermal alteration zone related to mineralizing fluids channelled in shear zones localized at the Grenville Supergroup–Flinton Group unconformity (e.g., Harding 1944; Springer 1982; Laing, Duke and Johnson 1987). Geochemically, both processes remove cations relative to the original host rock and, consequently, geochemistry alone cannot be used solely to identify the process responsible for the resultant rock.

During the 1990 field season, F.D. Ford (senior assistant) rediscovered another well-exposed Ore Chimney Formation section west of Marble Lake. Stripping revealed an intact section, described earlier and illustrated in Figure 13, with no structural break or localized deformation zones between the Flinton Group and the underlying rocks. The base of the section consists of weathered pillow lavas of the Kashwakamak Formation, which are overlain by black, garnet-biotite schist of the Ore Chimney Formation. The schist grades up into Bishop Corners Formation quartz metagranulestone and metapelite.

Three samples were analyzed from the Ore Chimney Formation at this site (samples 91RME-0188B, -0188C, -0188E, *see* Appendix 1). These samples show a decrease in Al_2O_3, TiO_2, iron (ferric and total), alkali (mainly due to Na_2O loss) content and an increase in SiO_2 with increasing distance from the contact. The average samples from the Harlowe section (Harnois and Moore 1988) plot in the field of felsic rocks of the Kashwakamak Formation, near the average composition of the Northbrook tonalite and the felsic units of the Kashwakamak Formation. Iron content of the Marble Lake samples is higher than that in the average samples from the Harlowe section. This difference can be attributed to the greater abundance of mafic source rocks beneath the Marble Lake site. Rare earth element patterns from the Marble Lake section show a slight decrease in the LREE upsection, possibly reflecting dilution due to introduction of detrital quartz reflecting the increasing sedimentary-like character of the higher part of the section. Most interestingly, no Eu anomaly is present. This is consistent with derivation from the underlying Kashwakamak Formation, but suggests weathering may have occurred under reducing conditions, perhaps due to a high groundwater table (cf. Rettalack 1991), otherwise Eu would have likely been leached from the paleosol.

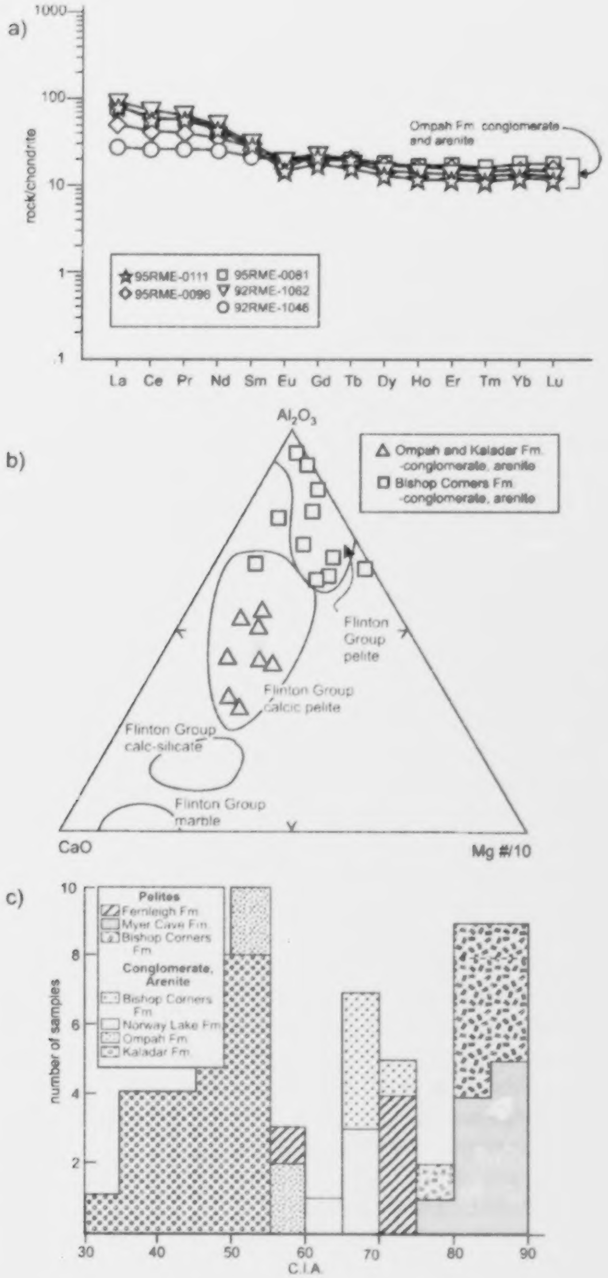

Figure 16. Geochemical data for Flinton Group rocks. a) Chondrite-normalized REE plot for metaconglomerate and meta-arenite of the Ompah Formation (samples 95RME-0096 and 95RME-0111, respectively). Variation in LREE-content of the Ompah Formation samples reflects the relative proportion of mafic volcanic detritus within the samples (compare samples 92RME-1046 (volcanic-rich) and 92RME-1062 (granitoid-rich). b) CaO–Al_2O_3–(Mg#/10) ternary diagram for samples of the Ompah Formation, the Kaladar conglomerate and the coarse clastic facies of the Bishop Corners Formation. The Ompah Formation and the Kaladar conglomerate plot in the field of calcic pelites. Details regarding this type of ternary plot are given in Easton (1997). c) Histogram plot of chemical index of alteration (CIA) values for various units of the Flinton Group. The Bishop Corners Formation samples fall into 2 groups, with the coarse clastic facies having lower CIA values than samples of arenites and pelites from the pelite-marble facies. Extremely low CIA values for the Kaladar conglomerate and the Ompah Formation reflect the high CaO contents of these rocks.

More intriguing is the observation that the elemental changes noted at Marble Lake are the same as those found at the Harlowe section, which also shows the same upsection trend of decreasing Al_2O_3, TiO_2, iron (ferric and total), alkalis, and an increase in SiO_2. The main differences between the 2 sites occur in the abundance of specific elements, not the trend of the observed changes. These differences in abundance (e.g., in total Fe contents, MgO, SiO_2) can be attributed to the fact that the Harlowe section is developed on intermediate to felsic members of the Kashwakamak Formation, whereas the Marble Lake section developed on mafic to intermediate composition rocks. The Harlowe section samples show a more noticeable positive Eu anomaly than the Marble Lake samples, with the magnitude of the Eu anomaly increasing upsection. The uppermost samples have patterns similar to Flinton Group metapelitic rocks, and it is possible the upper part of the Harlowe section includes a reworked, sedimentary component that is indistinguishable from the lowermost Flinton Group metapelite units.

Considering all the geochemical and field observational data, the arguments in favour of the paleosol interpretation of the Ore Chimney Formation are as follows. First, the Ore Chimney Formation has only been found beneath the Flinton Group. This would be expected for a paleosol because of the enhanced preservation potential. If due to alteration, particularly associated with deformation, Ore Chimney Formation might be expected to occur elsewhere in the area. Recognition of a possible Ore Chimney Formation horizon at high metamorphic grade in the Mosque Lake belt also supports that fact that development of the paleoregolith was widespread, and so far, it is only recognized beneath the Flinton Group.

Second, at the Marble and Mosque Lake sites, there is no evidence of a shear zone which might have localized alteration.

Third, at the 4 sites for which geochemical data are available, the geochemistry of the Ore Chimney Formation mirrors the chemistry of the underlying rock units. Furthermore, at the Harlowe and Marble Lake sites, similar upsection trends are observed. These observations are readily explained by a process of paleosol formation.

Fourth, weathering indices from the Ore Chimney Formation are consistent with moderate to intense weathering of the underlying rock units, although, hydrothermal alteration could produce similar results.

Fifth, as noted by Harnois and Moore (1988), there is no consistent relationship between quartz and carbonate veining and the chemistry of the Ore Chimney Formation, as might be expected if the Ore Chimney Formation were related to a mineralizing event along a shear zone controlled by the Flinton Group unconformity. In summary, the Ore Chimney Formation is most readily explained as a paleosol. Further investigation of Ore Chimney Formation profiles in the synoptic area, particularly over the Kashwakamak Formation, is needed to see if the trends observed here occur consistently and if the conditions of soil development can be further elucidated.

METACONGLOMERATES AND META-ARENITES

Data for these units, which includes the Kaladar conglomerates, as well as units assigned to the Ompah and Bishop Corners formations, are contained in Appendix 1. These rocks show the most variation of any of the Flinton units, in part, because these units are geographically widely dispersed and, in part, because these metaconglomerates and meta-arenites may be of different ages and provenance.

Kaladar Formation and Ompah Formation Metaconglomerates

The matrices of metaconglomerates from the Kaladar Formation (located south of the synoptic area on the southern margin of the Northbrook Tonalite), a matrix-rich Ompah Formation metaconglomerate from Sunday Lake, and an Ompah Formation meta-arenite are similar, overlapping the much tighter field of the calcareous upper Myer Cave and Fernleigh metapelites (Figure 16). This suggests that much of the mafic character of both units is the result of an original carbonaceous character. Although CaO contents are similar for conglomerate and arenite samples and the Fernleigh Formation samples, CO_2 contents are not, with CO_2 being low relative to CaO in both the Kaladar and the Ompah formations. This may reflect some loss of CO_2 during diagenesis or metamorphism for these units, which are generally preserved at higher grades than samples of the upper Myer Cave and Fernleigh formations. This is also suggested in a ternary plot of barium–strontium–(magnesium number/10)(*see* Figure 16b), which shows similarities in these elements between the Kaladar and the Ompah formation conglomerates and the upper Myer Cave and Fernleigh formations. These elements were chosen because barium and strontium can both substitute into calcite or gypsum structures. The overlap for all of these elements further suggests that the high CaO contents in the conglomerates of the Kaladar and Ompah formations reflects an originally calcareous component in these units. Ford (1992) made a similar argument for the Ompah Formation based on study of the metamorphic petrology of these rocks.

The similarity in major and trace elements is also reflected in rare earth element patterns (*see* Figure 16a). The Ompah Formation metalitharenite is identical to Fernleigh Formation metapelites, with the pattern from both formations suggestion derivation from a mixed source terrane approximating average continental crust. In addition, both the Fernleigh Formation and the Ompah Formation metalitharenite have lower total REE abundances than does the Myer Cave Formation, consistent with a significant calcareous component (observed in the Fernleigh, suspected in the Ompah). In contrast, the Ompah Formation metaconglomerate from near Sunday Lake has a unique REE pattern, characterized by low LREE and no Eu anomaly (*see* Figure 16a, sample 92RME-1046). This may be due to a high mafic volcanic source component to this sample, which is consistent with its location above the Sunday Lake mafic metavolcanic succession. Trace elements content (e.g., B, V, REE) of the Sunday Lake mafic metavolcanics and the Ompah Formation metaconglomerate are similar, supporting this interpretation (*see* Appendix 1, compare samples 92RME-0094 and 92RME-1062). Data from the granitoid-clast rich portions of the Ompah Formation metaconglomerate are similar to those for the Ompah Formation arenite (*see* Figure 16a, samples 92RME-1062, conglomerate; 95RME-0096, conglomerate matrix; and 95RME-0111, arenite).

The similarity in bulk composition between the Kaladar and Ompah formations metaconglomerates could indicate that the 2 units are correlative (*see* Figure 16a, samples 92RME-1062, Ompah Formation and 95RME-0081, Kaladar Formation), consistent with the occurrence of abundant tonalite cobbles in both units and the paucity of such cobbles in most other metaconglomerates within the area. The localization of the Kaladar and Ompah formations metaconglomerates adjacent to tonalite plutons, and the decrease in the abundance of tonalite cobbles away from the plutons suggests a very localized source region for the conglomerates, as does the geochemistry of the Ompah Formation metaconglomerate from Sunday Lake. Unfortunately, the calcareous nature of the matrix of these metaconglomerates hampers further interpretation of the provenance based on geochemical data (e.g., weathering indices cannot be determined, mobility of elements during decarbonation of the rocks).

Norway Lake Formation

Granite cobbles from the Norway Lake Formation metaconglomerates, as well as a meta-arenite intercalated with the metaconglomerates, overlap the range of Norway Lake and Abinger granites, which are the potential source of the cobbles (Figure 17). One cobble analyzed for REE has a pattern identical to the Norway Lake and Abinger granites (*see* Figure 17), further indicating that these metaconglomerates were derived locally, as suggested by the field relations previously discussed and the work of Cooke (1992). Again, very local source derivation is indicated.

Bishop Corners Formation

Metaquartzarenites and meta-arenites analyzed by Harnois and Moore (1988) lie in a discrete group apart from the other metaconglomerates, and samples of Bishop Corners Formation metapelites. Provenance of these rocks is more problematic, and they most likely came from a mixed source region. In the case of the Bishop Corners Formation metaconglomerates, this is suggested also by the presence of arenite-clast conglomerates, which may be either intraformational in origin or derived from early formed arenite (such as those at Norway Lake or within the Ompah Formation). Rare earth element data for these meta-arenites are limited to those collected by Harnois and Moore (1988), and indicates considerable local variation. For example, the meta-arenite from the Ore Chimney Mine show a significant contribution from Tudor Formation rocks, whereas the Addington Mine meta-arenites have a pattern similar to that for the Kashwakamak Formation, suggesting a more distal source region and less influence from the local basement. A muscovite-schist overlying the Northbrook Tonalite at Reids Lake, collected by Harnois and Moore (1988), has a REE pattern similar to the underlying tonalite, again suggesting local derivation of the schist.

In summary, the bulk composition of most Bishop Corners Formation metaconglomerates and meta-arenites reflects the underlying source rocks, suggesting local derivation of these metasedimentary rocks with little transport form the source, as noted by Moore and Thompson (1972, 1980). Of note is the relatively low SiO_2 content (69 to 75%) of most of these analyzed meta-arenites (*see* Figure 16c). True metaquartzarenites are only reported from the Ore Chimney Mine (Harnois and Moore 1988). This low SiO_2 content is also reflected in the REE data, as patterns show relatively high total REE (e.g., sample 91RME-0175, Appendix 1) consistent with a high-clay component in these meta-arenites. This suggests relative immaturity for the Bishop Corners Formation meta-arenites, which is consistent with the indications for derivation from local sources and low weathering indices (see "Weathering Indices").

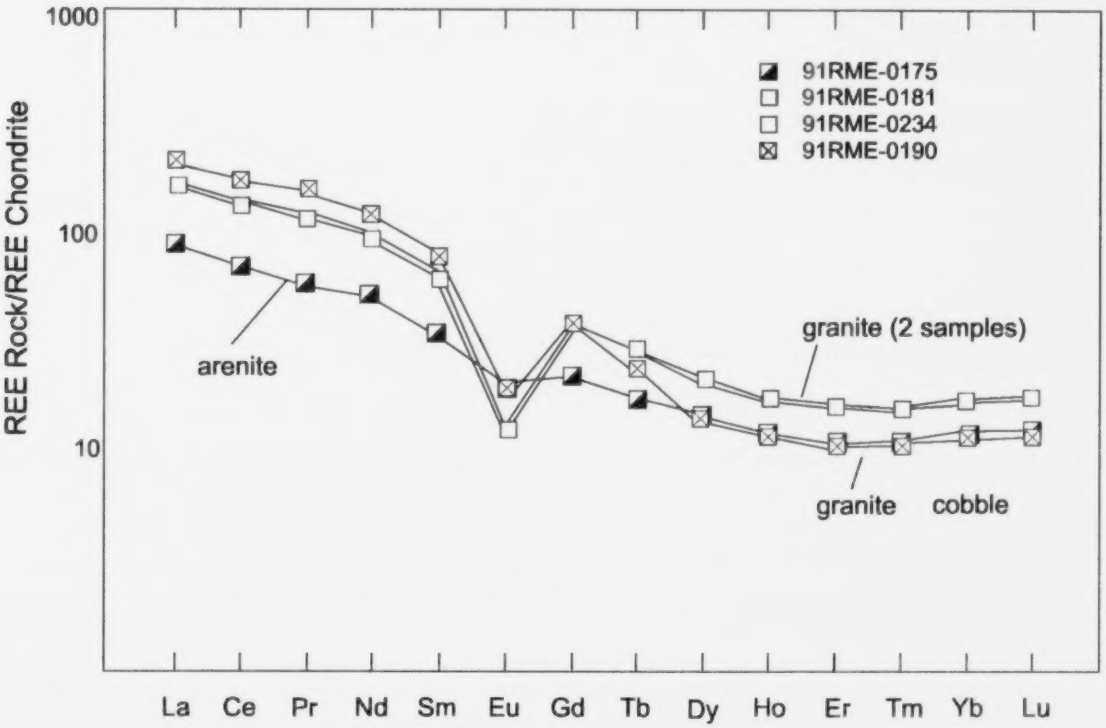

Figure 17. Chondrite-normalized rare earth element plot for metaconglomerate and meta-arenite of the Norway Lake Formation.

METAPELITES

Bishop Corners Formation

Rare earth element data from Bishop Corners Formation metapelites are listed in Appendix 1 (samples 91RME-0093; 92RME-0082; 93RME-0022). Despite the considerable range in metamorphic grade and geographic separation between these samples (some 40 km between 91RME-0093 and 93RME-0022), the patterns are notably similar. All the Bishop Corners Formation pelitic samples show REE patterns similar to those of the metavolcanic and the metaplutonic samples, suggesting that these underlying rock types supplied much of the detritus for the metapelites. Sample 92RME-0161 (*see* Appendix 1) is from a narrow belt of metapelite from the northern Palmerston Lake area along the northern margin of the Abinger Granite, and was sampled to test for possible correlation with the Flinton Group. The REE pattern is similar to Bishop Corners Formation metapelites and, in other plots, the sample lies in the range of Bishop Corners Formation samples.

Figure 17 shows rare earth element data from various Bishop Corners metapelites and meta-arenites near the Norway Lake granite. As noted previously, sample 91RME-0175 is a feldspathic meta-arenite intercalated with Norway Lake Formation metaconglomerates and has a REE pattern similar to the Norway Lake granite, the most likely source of detritus for the arenite. Sample 91RME-0232 is a metapelite located near the base of the Flinton Group on Little Mississagagon Lake, roughly 500 m south of the southern margin of the Norway Lake granite. The REE pattern for this sample also resembles that of 91RME-0175 and the Norway Lake granite and the Mazinaw Lake Formation metavolcanics, suggesting that these underlying rock units were an important source for the Bishop Corners Formation in this area. The REE pattern for sample 91RME-0232 is very different from other Flinton Group metapelite samples (*see* Appendix 1, not shown on Figure 17). Sample 91RME-0182 (*see* Appendix 1, not shown in Figure 17) is a hornblende-bearing felsite from the Sand Lake area, but is of uncertain stratigraphic assignment. Although its REE signature is similar to that of the nearby arenite (*see* Figure 17, 91RME-0175), its major and trace element chemistry differs in many respects, and, most likely, this sample represents an altered Mazinaw Lake Formation metavolcanic rock.

Kyanite-bearing metapelites of the Bishop Corners Formation are characterized by extremely low MgO contents, heavy REE depletion, and a limited range of Al_2O_3 contents. Intense chemical weathering of felsic members of the Kashwakamak Formation would produce all of these observed chemical distinctions, and high weathering indices (*see* Figure 16c) for these metapelites are consistent with this interpretation. If so, then it may mean that parts of the Bishop Corners Formation, particularly in the Fernleigh belt, represent transported or reworked soils of local derivation rather than being distally transported muds.

Myer Cave and Fernleigh Formations

Lower Myer Cave Formation Metapelites

These rocks are true pelites. There is no apparent difference in major elements between metapelitic and graphitic black slates of the lower Myer Cave Formation. In terms of trace metal contents, Myer Cave and Fernleigh formations rocks have Pb + Zn and Cu + Ni contents roughly double those in Bishop Corners Formation metapelites.

Upper Myer Cave and Fernleigh Formation Metapelites

These rocks are more calcareous, and overlap the field of the Fernleigh Formation rocks. This is consistent with field observations suggesting a gradational contact between the upper Myer Cave Formation and the Fernleigh Formation. These differences might be useful in stratigraphic mapping in more intensely deformed and metamorphosed parts of the synoptic area.

Myer Cave Formation Carbonates

Calcitic marbles differ from their Grenville Supergroup equivalents in several trace elements, containing higher abundances of strontium, boron, vanadium, and in having REE patterns resembling the over- and underlying Myer Cave Formation shales. Less data are available for dolomitic marbles from the Myer Cave Formation, but, in general, barium content is higher in the Flinton Group marbles, and some samples also show boron and vanadium enrichment. In the case of both strontium and barium, enrichments are considerable (range of 750–2500 ppm Sr in Flinton marbles versus 150–500 ppm Sr in Grenville Supergroup marbles). A plot of Ba–Sr–CaO (e.g., *see also* Easton 1995, Figure 2.2) illustrates the distinctive compositions of the Flinton Group marbles with respect to over 130 Grenville Supergroup marbles from the synoptic area.

As shown in Figure 18, REE patterns of Flinton Group calcitic marbles are similar to those seen in the Myer Cave Formation graphitic schists and metapelites. Total REE content decreases with decreasing Al_2O_3 content; the latter providing an indication of the noncarbonate component of the marble. This

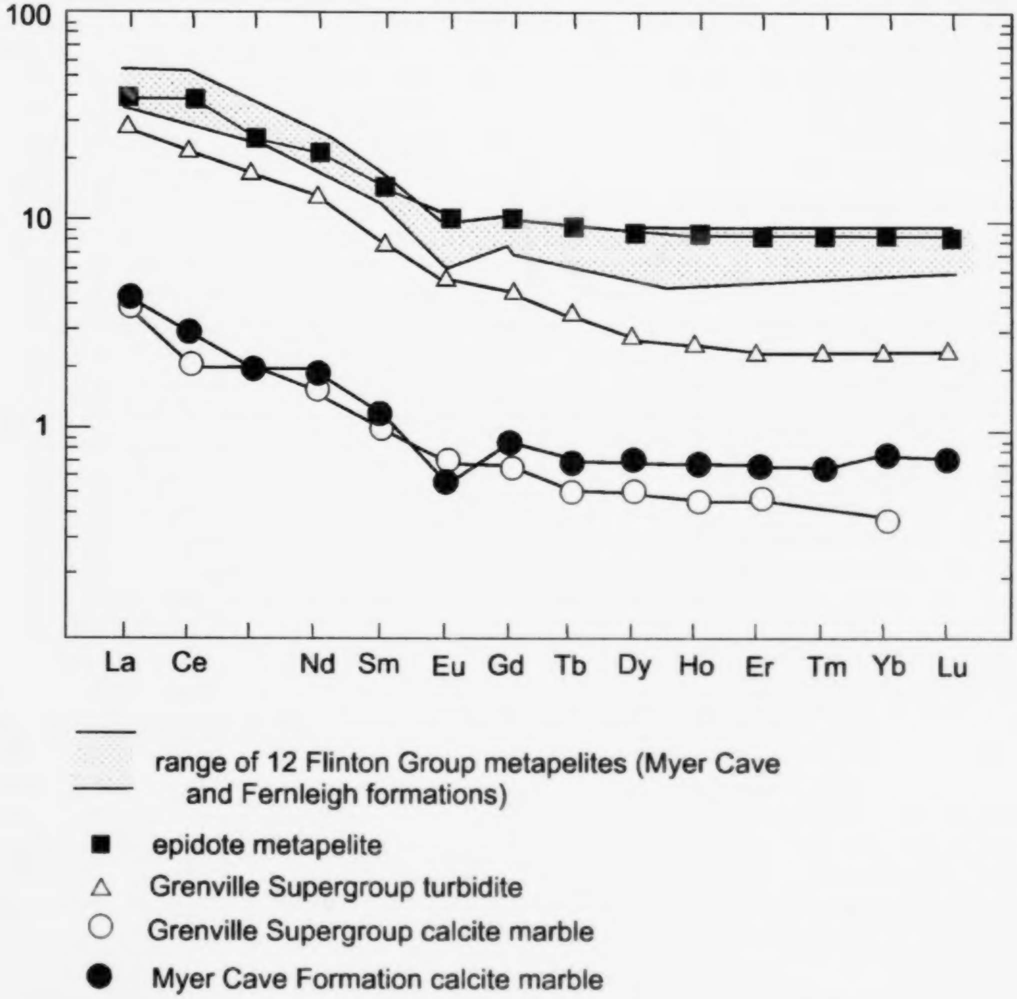

Figure 18. Chondrite-normalized REE plot for metapelitic and carbonate rocks of the Myer Cave and Fernleigh formations, Flinton Group. Samples of Mississagagon Formation rocks (Grenville Supergroup) are also shown for comparison.

correspondence suggests that the REE are hosted primarily in the clay component present in the marbles. The pattern for the Flinton Group marbles is distinct from Mississagagon Formation marbles, as the latter have REE patterns similar to those of the Kashwakamak Formation metavolcanics, which were probably being erupted, and resedimented, during carbonate deposition.

Only one sample of Myer Cave Formation dolomite has been analyzed (sample 95RME-0100, Appendix 1), and it is similar to Grenville Supergroup dolomite marble. Grenville Supergroup dolomite marbles have extremely low total REE abundances, and locally show negative cerium anomalies, with only small negative Eu anomalies (*see* Figure 18). Cerium anomalies in the dolomites may reflect interaction between the carbonates and seawater during deposition or diagenesis. Dolomite marble clasts from the Myer Cave Formation megabreccia are similar to Grenville Supergroup dolomites from the surrounding area (*see* Appendix 1, sample 94RME-0067), suggesting that the dolomite clasts within the megabreccia were derived from the Grenville Supergroup. If so, this indicates that a dolomitizing event and possible regional metamorphism affected the Grenville Supergroup prior to Myer Cave Formation deposition.

The abnormally high barium and strontium contents of the Myer Cave Formation carbonates, and their linkage with carbonate mineral (e.g., Ca and Mg) content, not detrital mineral content (e.g., Al_2O_3) requires explanation. The most likely scenario is that the Myer Cave Formation carbonates were deposited in an evaporitic basin, either as primary aragonite or gypsum, with the high strontium and barium contents due to enrichment due to brine formation. Barium is particularly informative in this regard, as its abundance is independent of potassium, rubidium, or aluminum content of the rocks, which would be expected if some or all of the barium was derived from detrital sources. Alternatively, these elements could represent a diagenetic process that occurred subsequent to lithification, as gypsum is a common diagenetic cement in arid environments (Retallack 1991). In modern environments, the presence of these elements could reflect an organic origin, as many modern organisms such as foraminifera secrete tests rich in either strontium or barium. This explanation is unlikely because there is no evidence for shell-forming organisms during the late Mesoproterozoic.

Further evidence for an evaporitic origin is the fact that the dolomite member of the Myer Cave Formation only occurs low in the section, beneath the calcitic marbles, and dolomite marbles of the Grenville Supergroup commonly underlie the Flinton Group. Dolomitization of carbonates beneath evaporitic sequences is a common occurrence, and is related to the evaporitic brines altering the underlying strata (Krauskopf 1967; Sonnenfeld 1984; Hardie 1991). The high boron content of the Bishop Corners Formation, the Myer Cave Formation dolomitic marbles, and some of the adjacent Grenville Supergroup dolomite marbles is also consistent with this model. In addition, mineral deposits at lower metamorphic grades associated with these dolomite marbles commonly contain sulphosalts, which might also be a reflection of an earlier brine-related alteration of the underlying rocks, which is partially preserved despite prograde metamorphism. Evaporitic minerals have been previously reported from the Grenville Province. Anhydrite has been reported from the Balmat–Edwards zinc deposits in upper state New York at comparable metamorphic grade, but only from depth. Determining if the Myer Cave Formation carbonates were deposited as evaporites has important implications for the application of exploration models for mineralization within the synoptic area. Unfortunately, little literature exists on metamorphosed evaporites, particularly their geochemistry, as most workers have assumed that these deposits were mobilized (e.g., as salt domes) during burial and orogenesis (cf. Sonnenfeld 1984; Hardie 1991). Even if the Myer Cave Formation carbonates cannot be demonstrated to have an evaporite origin, strontium and barium appear to be effective discriminants of Grenville Supergroup versus Flinton Group carbonates.

WEATHERING INDICES

The presence of a possible paleosol beneath the Flinton Group and the wide variation in rock types within the Flinton Group meant that the effects of weathering needed to be examined, particularly with respect to evaluating the rare earth element data as an indication of provenance. To test for weathering effects, the Chemical Index of Alteration (CIA; Young and Nesbitt 1983) was applied.

$$\text{CIA} = [Al_2O_3/\ Al_2O_3+CaO^*+Na_2O+K_2O] \times 100, \text{ where } CaO^* = \text{non-carbonate CaO}$$

Results are illustrated in Figure 16c, and are provided for all samples listed in Appendix 1. The CIA values were not calculated for carbonate rocks within the Flinton Group, as they are chemical precipitates. The CIA index is similar to the Chemical Index of Weathering of Harnois (1988b), except that the latter uses molecular proportions rather than weight %. The CIA index differs from the ACNRATIO of Harnois and Moore (1988) in including K_2O and correcting for CaO bound with carbonate.

Fresh rocks generally have a CIA value of 50 to 60. Chemical weathering results in a higher CIA value, due mainly to the production of clay minerals. Intense chemical weathering produces CIA values greater than 85, although intense hydrothermal alteration can produce similar results. The CIA values shown in Figure 16c show distinct formational differences. In brief, Bishop Corners Formation meta-arenites show CIA values consistent with modest chemical weathering of the source region, whereas metapelites from the Ore Chimney, Bishop Corners and Myer Cave formations show evidence of more intense chemical weathering, consistent with the micaceous (formerly high clay content) character of these rocks (Table 8).

Ore Chimney Formation

The CIA values range from 66 to 85, with most values lying near 75. In both the Harlowe and the Marble Lake sections discussed previously, the lowermost sample has the highest CIA value, is consistent with the higher Al_2O_3 and ferromagnesium content (Fe_{total} + TiO_2 + V) of these samples, and is in agreement with the suggestion that these lowermost samples are paleosols resulting from chemical weathering. The decrease in CIA content upsection probably reflects influx of sedimentary detritus, which is also consistent with field evidence which indicates a more sedimentary-like character for these rocks (increased lamination, higher quartz and grit contents; *see also* Young 1985; Harnois and Moore 1988). Although higher CIA values might be expected from a lateritic soil, it is possible that CO_2 mobility, both during diagenesis and regional metamorphism, has lowered the CIA values within the Ore Chimney Formation.

Kaladar Formation Conglomerate and Ompah Formation

Both units have extremely low CIA values, with the Kaladar Formation conglomerate having CIA values in the 30 to 40 range, values similar to those obtained from marbles. These low CIA values, combined with the high CaO contents of many of these rocks (8 to 14%), may reflect a loss of CO_2 during diagenesis or metamorphism, which, as noted above, renders the CIA calculation suspect, as noncarbonate CaO cannot be readily calculated. Despite this, the similarity of the calculated CIA values is consistent with the aforementioned geochemical similarities between these formations.

Norway Lake Formation Granitoids and Conglomerate Cobbles

These rocks were considered separately because of the strong field and geochemical evidence for local source derivation. This is also reflected in the CIA values, with the source Norway Lake and Abinger granites showing a tight cluster of values (58 to 62), similar to the granite cobbles believed to be derived from these granite plutons. The CIA values are slightly higher for the cobbles (61 to 66), and are similar to that from an interbedded arenite (67). This is consistent with local source derivation of a minimally weathered host rock. These values are similar to Ore Chimney Mine area meta-arenites.

Table 8. Summary of provenance indicators for the Flinton Group.

Unit	Source Area	CIA Value	Rare Earth Element Patterns	Other Data or Comments
Fernleigh Formation	R	NR	Average continental crust	Calcareous
Myer Cave Formation				
Unlaminated Schist member	R	NR	Average continental crust	Calcareous
Carbonate member	R	NR	Similar to Myer Cave Formation pelites and schists	High strontium and boron may indicate evaporite origin or diagenesis involving gypsum cements
Pelite and Laminated Schist members	R	76–85	Average continental crust	May be deposited under anoxic conditions as black, organic-rich shales
Bishop Corners Formation				
Fernleigh belt metapelite	L	80–85	Felsic KWF and EPS source	One sample reflects NLG source, high boron
Norway Lake area metapelite, meta-arenite, metaconglomerate	L	66–68	NLG source	
Ore Chimney Mine meta-arenite and metaconglomerate	L-R	ND	Tudor Formation dominated source	U/Pb data of Sager-Kinsman and Parrish (1993) indicate local and regional sources
Addington Mine metaconglomerate	R	ND	Average continental crust and felsic KWF and EPS source	
Ompah Formation				
Sunday Lake metaconglomerate	L	NR	Local mafic volcanics	Calcareous
Tonalite clast metaconglomerate	L	NR	No data	Calcareous, tonalite cobbles from EPS rocks?
Meta-arenite	L	NR	Similar to Fernleigh Formation	Calcareous, mixture of mafic KWF and EPS rocks?
Kaladar conglomerate	L	NR	No data	Calcareous, tonalite cobbles from EPS rocks?
Ore Chimney Formation	L	66–85	Same as underlying units	Probable paleosol

Notes and Abbreviations: CIA = chemical index of alteration; EPS = Elzevir Plutonic Suite (Elzevir, Northbrook, Cross Lake tonalites); KWF = Kashwakamak Formation; L = local; ND = no data; NLG = Norway Lake and Abinger granites and Mazinaw Lake Formation felsic metavolcanic rocks, NR = not reliable; R = regional. Note: CIAs shown as not reliable are due to high CaO or CO_2 contents in the rocks, which bias the CIA calculation.

Bishop Corners Formation

Two groups are present, samples with CIA values between 66 to 73 and samples with CIA values between 80 and 85. Both groups include meta-arenites and metapelites. The groups may be geographic, as the Ore Chimney Mine meta-arenites and metapelites (Harnois and Moore 1988) have consistently low CIA values, whereas samples from the Fernleigh belt generally have high CIA values, especially the kyanite-bearing metapelites. This is consistent with the observation made previously that the kyanite-bearing pelites have low MgO and HREE, and that they appear to be derived from weathering of felsic-members of the Kashwakamak Formation or the Elzevir plutonic suite. It is also consistent with the pelitic (high original clay content) nature of the samples. Sample 92RME-0082 from Mosque Lake (*see* Appendix 1), which contains relict kyanite, is an exception, having a CIA of 68; however, this sample has higher than normal MgO, CaO and Na_2O, and its bulk composition may have been altered after kyanite formation, especially as this rock contains sillimanite (after kyanite) which is the result of the process of breaking down to form another aluminosilicate mineral. As noted previously, in the case of the meta-arenites, the low CIA values of some of these rocks may reflect source immaturity (and limited weathering).

Myer Cave Formation

The CIA values for metapelite from the lower Myer Cave Formation range from 76 to 85, similar to values observed for the Bishop Corners Formation metapelites, and are consistent with the pelitic or black slate character of the rocks. Samples from the upper Myer Cave and Fernleigh formations have lower CIA contents (51 to 72) than the underlying metapelitic units; however, the calcareous nature of these units renders interpretation of these values problematic. In some cases, CO_2 content in these rocks exceeds CaO content, although this can be accounted for by binding of CO_2 with both CaO and MgO in dolomite. As a consequence, however, calculation of the noncarbonate CaO component of these rocks is suspect, and it is likely that the low CIA values for these formations most likely reflect the calcareous nature of the rocks and are not a reflection of weathering intensity.

Provenance of the Flinton Group

Table 8 summarizes all the provenance data available for the Flinton Group. The Myer Cave and Fernleigh formations appear to be derived from a regional source, because their REE patterns are similar to those for average continental crust, and because little along-strike lithological or geochemical variation was observed in this units.

Conflicting data come from the Bishop Corners Formation (as it is currently defined). Bishop Corners Formation metapelites in the Fernleigh belt, although having high CIA values typical of muds, have REE patterns, as well as major element compositions, that can be matched with local sources. The dominant source approximates the composition of the felsic members of the Kashwakamak Formation and the Northbrook–Cross Lake tonalites, although, near the Norway Lake granite, some metapelites shown compositions similar to the Norway Lake–Abinger granites and the Mazinaw Lake metavolcanic rocks. Metaconglomerate and meta-arenite units adjacent to the Norway Lake granite have CIA values and major and trace element compositions consistent with derivation from that pluton, as indicated by field observations. In contrast, the Addington Mine metaconglomerate, studied by Harnois and Moore (1988), has a major element and REE composition indicating a more regional origin, including both the Tudor and Kashwakamak formations.

Although the Ore Chimney Mine meta-arenites have REE patterns suggesting a strong Tudor Formation source, detrital zircons from a meta-arenite at the Ore Chimney Mine, studied by Sager-Kinsman and Parrish (1993), show populations of zircons with ages of 1877, 1460, 1335, 1282 to 1273, 1229, and 1198 to 1149 Ma, with the 1282 to 1273 Ma and the 1180 to 1149 Ma populations being the largest. Peters (1993) studied the detrital zircon population of meta-arenite clasts from an overlying metaconglomerate at the Ore Chimney Mine, and reported zircons with ages of 2708, 1981, 1914, 1726 to 1789, 1660, 1458 to 1463, 1329, 1263 to 1299, and 1187 Ma. Peters (1993) also noted that the zircons ranged from euhedral to subrounded to rounded, indicating a mixture of source regions with varying degrees of transport. As might be expected the euhedral zircons gave the younger ages (1463 to 1263 Ma), consistent with the age range of the country rocks (1250 to 1276 Ma) and rocks from the Central Gneiss Belt now located some 50 km to the north. Thus, on the basis of the previous field observations (Moore and Thompson 1980; Moore and Morton 1986), and the similarity in detrital zircon populations between the meta-arenite cobbles and the meta-arenite proper, Peters (1993) concluded that the meta-arenite clasts in the Bishop Corners Formation metaconglomerate were intraformational in origin. In both detrital zircon studies, the most frequent age range encountered was 1250 to 1299 Ma, similar to the known age range of 1282 to 1229 Ma for rocks from the Mazinaw domain, suggesting a dominant local source, but with a more distal source also making a significant contribution to the overall composition of the meta-arenites and metaconglomerates.

Less REE data are available for the Ompah Formation and the Kaladar conglomerate. The Ompah Formation metaconglomerate from Sunday Lake has a major and trace element composition consistent with local derivation from adjacent mafic metavolcanics. Both the Ompah Formation and Kaladar metaconglomerates contain tonalite clasts, most likely derived from adjacent tonalite intrusions. Both units are calcareous. The Ompah Formation metalitharenite has a REE pattern similar to that of the Fernleigh Formation, suggesting derivation from a mixed source terrane, however, a mixture of tonalite and mafic and felsic metavolcanics from the Sunday Lake area could produce a similar pattern. In general, the Ompah Formation and the Kaladar conglomerate appear to be more locally derived than do the Bishop Corners area metaconglomerates.

These differences in source regions, particularly in the metaconglomerates and meta-arenites raises some questions about the existing stratigraphy. Previous workers have generally assumed that all metaconglomerate units within the Flinton Group were roughly coeval; however, this may not be the case. Locally derived sequences are the Kaladar conglomerate, the Ompah Formation, and the Norway Lake succession. Two of these sequences are calcareous; all 3 contain cobbles derived from adjacent granitoids. Only in the Ompah area is one of these metaconglomerate units in contact with other Flinton Group formations. Thus, on the basis of stratigraphic and structural arguments, Ford (1992) suggested that the Ompah Formation was older than the Flinton Group strata in the Fernleigh belt, including the Bishop Corners Formation metapelites. In the Ompah area, the Ompah Formation is folded by both F_1 and F_2 structures. The belt-like nature of the Kaladar and Norway Lake metaconglomerate sequences makes determination of folding history more difficult; however, if the Norway Lake granite itself is folded, then the metaconglomerate has also been folded by both F_1 and F_2 structures.

Both the Ore Chimney Mine and Addington Mine metaconglomerates and meta-arenites show either chemical or detrital mineral evidence, or both, for derivation from a more regional source terrain. In addition, these units include meta-arenite clasts, suggesting that earlier Flinton Group meta-arenites may have been present in the area. Both sites occur in synclines, which Moore and Thompson (1972, 1980) regarded as being the typical structural setting for the Flinton Group. It can be argued that the presence of meta-arenite clasts and the evidence for a more regional source region indicates that the Bishop Corners area metasedimentary rocks might have formed in a different depositional setting, and perhaps are younger in age than the Ompah, Kaladar and Norway Lake formations metasedimentary rocks. This is also consistent with the observation that some of the Bishop Corners area metasedimentary rocks occur at the base of the Fernleigh belt in this area, and that these metaconglomerates are roughly correlative with the Bishop Corners Formation metapelites, unlike the relationship observed by Ford (1992) in the Ompah area. Detrital zircon studies on the Ompah, Kaladar and Norway Lake formations metaconglomerates and meta-arenites may help resolve the age relationships between these different metasedimentary sequences.

Depositional Setting of the Flinton Group

Moore and Thompson (1980) suggested that the paucity of locally derived clasts within the Bishop Corners Formation was due to deep weathering, either in a tropical or subtropical environment. Thus, the lowermost units were pelites and quartz arenites. This subsequently gave way to erosion of fresh rocks as sources were elevated, residual soil stripped, and plutons unroofed, which would have generated the Bishop Corners and Ompah formations conglomerates. This suggestion is neither supported nor refuted by the geochemical data available for the Bishop Corners Formation. The CIA value of the metapelites of the Bishop Corners Formation are high (80 to 85, *see* Table 8), but they are not as high as one would expect from a sediment derived from deep weathering (CIA >90). Introduction of carbonate (i.e., calcium) during diagenesis and weathering of the pelites could, however, skew the calculated CIA to lower values. The detrital zircon data of Sager-Kinsman and Parrish (1993) and Peters (1993) indicate that local sources did provide significant input into the Bishop Corners Formation. More intriguing is what was the source of the 1157 Ma grains found in the Bishop Corners Formation. No plutons of this age have yet been reported from Mazinaw domain. Did they come from the vicinity of the Maberly shear zone, some 50 km to the southeast, due to uplift and erosion related to Composite Arc Belt–Frontenac–Adirondack collision at circa 1160 Ma?

Evidence from the Myer Cave Formation suggests deposition in a sub-arid, evaporitic environment. First, the lower dolomite unit of the Myer Cave Formation is enriched locally in barium. Grenville Supergroup carbonate rocks adjacent to the Fernleigh belt are commonly dolomitic, likely due to dolomitization, and it is possible that the dolomitization in the adjacent Grenville Supergroup rocks and the lower dolomite unit might be related to diagenetic fluid movement (e.g., evaporitic brines). Second, the main carbonate member of the Myer Cave Formation has a high Sr content, which, as discussed previously, may reflect the presence of original gypsum cement. This would argue for an evaporitic depositional environment. The high boron content of the Flinton Group rocks in the lower grade portion of the Fernleigh belt, as evidenced by both the presence of abundant tourmaline and boron analyses, also suggests an evaporitic origin. Third, the lower Myer Cave Formation in the lower grade portion of the Fernleigh belt is carbon rich. This could be the result of either biologic productivity or rapid sedimentation in euxinic conditions. Either process would also explain the regularly spaced laminae in the lower Myer Cave Formation. In the case of a biologic process, lamination would be due to regular biologic productivity events? A change from a euxinic to oxygenated environment occurs with increasing stratigraphic height in Myer Cave Formation, based on Mn/Al and Mn/Fe ratios in the upper units.

Moore and Thompson (1972, 1980) suggested a fluvial environment for deposition of the coarse clastic units of the Flinton Group and a shallow marine setting for the pelitic and carbonate units, both occurring in an extensional environment. In contrast, Easton and Ford (1991, 1992) postulated that the Flinton Group was deposited in a fluvial–lacustrine environment, with deposition in part controlled by rift valleys, which resulted in longitudinally oriented alluvial-fan and braided stream trunk systems (Figure 19). The braided stream trunk systems would have helped to transport sediment long distances, from say the area of the Maberly shear zone across Sharbot Lake to northwestern Mazinaw domain. This model explains the preservation of the Flinton Group in synformal, linear belts, as well as the localized faulting present along the Flinton unconformity, and associated mineralization. The alternating pelite–carbonate beds within the Fernleigh Formation may reflect annual variations in sediment supply into the rift valley lakes, and the ubiquitous and abundant presence of tourmaline throughout the Flinton Group (e.g., Thompson 1972; Easton 1988) would be expected in an arid, fault-controlled depositional environment. The Myer Cave Formation megabreccia unit probably formed by collapse of a cliff into a lake, allowing for the incorporation of Myer Cave Formation and Grenville Supergroup blocks in a pelitic matrix.

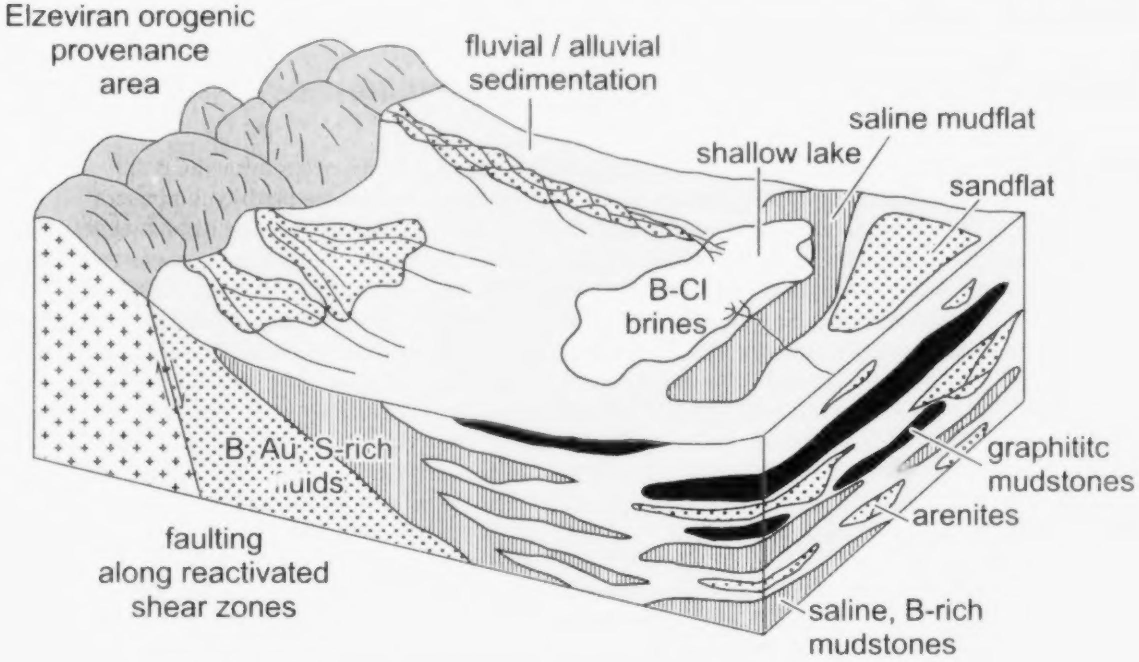

Figure 19. Sketch showing possible depositional model for the Flinton Group.

The fluvial–lacustrine model has metallogenic implications. Quartz-sulphide-carbonate veins, containing a variety of metals, including Au, Cu, Pb, Zn, and As, are commonly found near the Flinton Group unconformity, although many veins are hosted entirely in Grenville Supergroup strata. The depositional setting of the Flinton Group outlined herein is similar to that described by Lefevbre (1989) for the Zambian copper deposits, as are the metal associations (Au, Cu, Pb, Zn, and As). Mineralization is the result of fluid movement along fault systems, with fluid flow localized in permeable units below, along, and above the unconformity. In addition, black shales deposited in anoxic lakes are also locally mineralized (e.g., laminated sulphide schists of the Myer Cave Formation).

Felsic Intrusive Rocks: Skootamatta–Kensington Suite (unit 24)

Potassic, felsic intrusive rocks of the Skootamatta–Kensington Suite (Easton 1992b; Corriveau et al. 1990), with an age between 1090 and 1065 Ma, occur through most of the Central Metasedimentary Belt, but are notably absent from the Mazinaw domain. The Skootamatta–Kensington Suite is equivalent to the Monzonite–Diorite Suite of Lumbers et al. (1990). In Ontario, the Skootamatta–Kensington Suite consists mainly of monzonite, syenite or alkali-feldspar granite, with minor amounts of diorite and pyroxenite. To date, no explanation has been presented to explain the absence of these rocks from Mazinaw domain, although it is conceivable that plutons of this suite were simply not emplaced at the crustal level represented by the Mazinaw domain during emplacement of these intrusions during Geon 10.

The Skootamatta syenite intrusion present within Grimsthorpe domain in the extreme southwestern corner of the synoptic area is a member of this suite. This body consists mainly of pink-weathering, medium-grained syenite, with minor amounts of darker weathering monzonite. The Skootamatta syenite was emplaced at 1080 Ma (S.D. Carr, geochronologist, Carleton University, Ottawa, written communication, 1998). The geology and geochemistry of this intrusion has been well described by Easton and Ford (1994a, 1994b) and Harris (1991).

Felsic Intrusive Rocks: Pegmatite Veins (unit 25)

Deformed and undeformed white tonalite and pink granite pegmatite veins occur throughout the northwestern part of the synoptic area, but are particularly abundant within the marble-dominated supracrustal belt that cores Palmerston and Canonto Lake. White weathering, tonalite pegmatite veins are most common in the marbles, whereas pink weathering granite pegmatite veins are more common cutting gneissic plutonic rocks. The deformed pegmatites are protomylonitic. Corfu and Easton (1995) submitted for geochronological analysis an undeformed granite pegmatite vein that exhibited crosscutting relationships with a protomylonitic granite pegmatite. The undeformed vein gave a zircon U/Pb age of 1079±2 Ma, whereas the deformed vein gave a minimum age of 1063±5 Ma. The discrepancy between the zircon ages and the observed relative age relationships can be explained by subsequent lead loss in zircons present in the deformed vein, with a maximum age of circa 1080 Ma being permissible for emplacement of this vein. Alternatively, the age difference between the 2 veins could be real, with the difference in deformation textures reflecting a process of heterogeneous regional deformation or *in situ* deformation during magmatic emplacement.

Pegmatite distribution within the synoptic area corresponds closely to the areas of highest metamorphic grade. There is no apparent localization of pegmatite veins along regionally extensive shear zones or fault systems. Derivation from melting of local rock types (granite plutons, clastic metasedimentary rocks) is a viable mechanism for formation of the tonalite and granite pegmatite veins.

Coarse-grained to pegmatitic, muscovite-quartz-plagioclase, veins cut Flinton Group rocks in the western part of the synoptic area and, as with the tonalite and granitic pegmatite veins, are closely associated with the areas of highest metamorphic grade. They are particularly abundant above the muscovite-breakdown isograd. Corfu and Easton (1995) obtained a zircon age of 984±4 Ma from one of these veins located immediately east of the synoptic area near Clyde Forks. Thus, these veins postdate peak metamorphism that affected the Flinton Group between 1040 and 1020 Ma (Corfu and Easton 1995), and are clearly older than the circa 1080 Ma tonalite and granite pegmatite veins cutting plutonic rocks and Grenville Supergroup strata in Mazinaw domain.

Mafic Intrusive Rocks (unit 26)

Fine-grained, weakly metamorphosed, shallow-dipping to subvertical, east-northeasterly trending, diabase dikes are particularly abundant crosscutting the Abinger Granite on both sides of Mazinaw Lake. They are well exposed in the section exposed along Old Walt Rock in Bon Echo Provincial Park. These fine-grained, greenish weathering dikes exhibit chill margins and sharp contacts, and are generally slightly recessive weathering. In thin section, these dikes consist of fine-grained aggregates of hornblende and plagioclase, are weakly foliated, and preserve a poorly defined ophitic texture. The relationship of these dikes to other regional dike swarms (e.g., the 1160 Ma Frontenac dike swarm) is unknown.

NEOPROTEROZOIC

Mafic Intrusive Rocks: Grenville Dike Swarm (unit 27)

South of Quinn Lake, field party personnel located a fresh, unmetamorphosed diabase dike with a trend parallel to one of the regional northwest-trending faults in the synoptic area. This dike is similar in composition and field appearance to Grenville Swarm diabase dikes associated with Ottawa–Bonnechere graben faults north of the map area (e.g., Lumbers 1982; Easton 1992b). It has no expression on the regional aeromagnetic map (Geological Survey of Canada 1952c).

PALEOZOIC

Sedimentary Rocks (unit 28)

Several small outliers of Paleozoic strata were found in the Palmerston Lake area in the northeast part of the synoptic area. Northeast of Sunday Lake (UTM 361780E 4987810N), a rusty-weathering, hematite-cemented, clast-supported conglomerate consisting of angular to subangular fragments Grenville Supergroup rocks crops out. Near Twin Lakes (UTM 361480E 4996285N), a calcite-cemented quartz arenite outcrop contains large hematite fragments. Northeast of Redhorse Lake (UTM 358980E 4996225N), an outcrop of calcitic limestone contains angular quartz grit and rare cobbles of gneiss and pegmatite. All these Paleozoic units are locally derived, and little transported, and probably represent the basal part of the Paleozoic sequence within the map area. They may be correlative with either the Covey Hill or Shadow Lake formations, which are generally regarded as Cambrian in age (Johnston et al. 1992).

Precambrian rocks within the eastern part of the Palmerston Lake are extremely friable and appear to have undergone extensive weathering. A possible explanation for this phenomenon is that the current level of exposure lies close to the position of the now eroded Precambrian–Paleozoic unconformity, and the observed weathering is the result of the pre-Paleozoic weathering surface that has been described elsewhere in southern Ontario (e.g., Di Prisco and Springer 1991).

Calcite-Barite Veins

Calcite ± barite ± fluorite ± galena veins are commonly associated with Ottawa graben faults closer to the Ottawa River, and are interpreted to be Ordovician in age (Carter 1984; Williams 1991; Easton 1992b). Only one such vein has been documented within the synoptic area (Moore and Morton 1986), and is too small to display on Map P.3443. It occurs near Green Bay on Mississagagon Lake area within the Marble Lake map area (Moore and Morton 1986). The Green Bay vein varies in width from 1 to 15 cm, and can be traced discontinuously over a distance of up to 25 m. Vein minerals are generally coarse grained, consisting mainly of calcite, with minor barite, quartz, pyrite, and fluorite.

The Marlhill calcite mine (Smith 1958) was situated in an extremely wide vein, up to 30 m across, that was located along the trace of the Plevna fault 20 km southeast of the synoptic area. No veins of such width have been documented from the synoptic area, although it is possible that they may be present in low-lying areas present along northwest-trending faults in the synoptic area.

CENOZOIC

Quaternary

PLEISTOCENE AND RECENT

The Quaternary geology of the synoptic area, covered by NTS sheet 31 C, was studied by Henderson (1972). Aggregate resource inventories for townships in Frontenac County and in the County of Lennox and Addington are provided in Ministry of Natural Resources (1987b) and (1987a), respectively.

Most of the area is underlain by thin, discontinuous till, which is generally less than 3 m thick. Major transportation corridors in the synoptic area, most notably Highway 41 and Frontenac County road 509, locally follow topographic lows dominated by glaciofluvial sediments. The largest of these are located south of Mazinaw Lake, and in a northeast-trending belt from Marble Lake to Sand Lake to Palmerston Lake to Canonto Lake. The deposits of the latter belt reflect the influence of a former glacial lake that extended from Marble Lake to Canonto Lake.

A large glacial spillway system begins at the south end of Mazinaw and Marble lakes, and trends to the southeast along the Grimsthorpe–Mazinaw domain boundary toward Flinton and Tweed (Henderson 1972). Southeast of the synoptic area, this drainage system is marked by a number of large gravel flats and major esker segments. A large kettled, deltaic, ice-contact deposit is located north of Plevna in the Shaw Lake area, and was deposited in a former glacial lake that developed due to blockage at the south end of Marble Lake (Henderson 1972).

Modern Alluvium Survey

The southwestern corner of the synoptic area was included in the area covered by a modern alluvium sampling survey that was conducted by the Ontario Geological Survey in 2004 (Felix, Reid and Easton 2006; Felix and Reid 2006). The purpose of this section is to relate specific observations made during that study to the bedrock geology of the area, especially with respect to metamorphic and sulphide minerals such as gahnite, kyanite, chalcopyrite and pyrite. Most of these minerals are classified as metamorphic/magmatic massive sulphide indicator minerals (MMSIM®[4]). No kimberlite indicator minerals were reported from the synoptic area, or from the area of the Tweed modern alluvium survey (Felix, Reid and Easton 2006).

Samples from the synoptic area are from 4 main geographic areas, with sample locations shown on Map P.3443. Samples 03JRMA-114 and 03JRMA-116 are from the shore of Mazinaw Lake, and samples 03JRMA-039 and 03JRMA-150 are from the shore of Skootamatta Lake. Sample 03JRMA-112 is from Norway Lake. Samples 03JRMA-104, 03JRTM-051 and 03JRSG-008 are from the area immediately south of Mazinaw Lake. For the most part, these samples contain few or no MMSIM®, metamorphic minerals, or gold grains.

The exception is sample 03JRMA-150, which contains 23 gahnite grains, the most from any sample collected from the entire modern alluvium study area. Gahnite is a useful MMSIM® as it serves as an indicator for zinc mineralization and is stable in oxidizing surficial environments (Morris et al. 1997). There are 3 modes of occurrence for gahnite, which include VMS (polymetallic), rare earth elements (REE) pegmatites and peraluminous granites (Ontario Geological Survey 2001). Using electron microprobe data, compositional differences between gahnites from various environments make it possible to discern the mode of occurrence. Gahnites from VMS deposits typically have MgO concentrations >2 weight %, whereas those from REE pegmatites and peraluminous granites tend to have MgO concentrations that are <2 weight % (Morris et al. 1997).

Mineral chemistry for all gahnite grains from sample 03JRMA-150 can be found in Felix and Reid (2006). More than half of the grains from these 2 samples had MgO concentrations >2 weight % suggesting a VMS-type deposit as a possible source. It is important to note, however, that these samples did not yield any chalcopyrite and only background concentrations of pyrite. Sample 03JRMA-0150 is located in westernmost Mazinaw domain, at the western end of a belt of Mazinaw Lake Formation metavolcanic rocks, known to contain FIII rhyolites and sulphide mineralization (Easton and Ayer 1994). In Archean greenstone belts, FIII rhyolites are associated with VMS mineralization. The abundance of gahnite grains in this sample, in association with favourable host rocks, makes this volcanic belt a prime exploration target.

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[4] MMSIM is a registered trademark of Overburden Drilling Management Limited, Nepean Ontario.

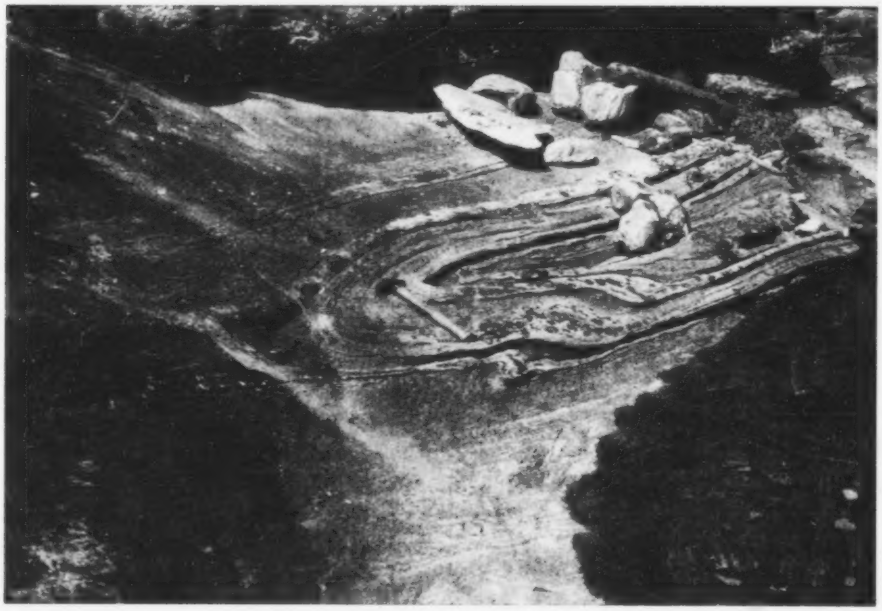


Photo 36. Interference fold developed in marble in the north-central part of the synoptic area (UTM Zone 18, 340675E 4996470, NAD27). Hammer handle is 30 cm long.

Photo 37. Excavated fault gouge along northwest-trending faulting cutting the Norway Lake granite.

Structural Geology

FOLDING

The degree of pre-Flinton Group folding within the Grenville Supergroup is difficult to ascertain. Moore and Thompson (1972) and Thompson (1972) recognized 3 main folding events affecting the Flinton Group, as shown in Table 5, observations confirmed by subsequent studies (e.g., Rivers 1976; Karboski 1980, Jackson 1980, Anderson 1988, Easton 1992b; Ford 1992). As noted by Ford (1992), parts of the Myer Cave and Fernleigh formations in the Ompah area may have only seen 2 to 2.5 of the 3 phases of deformation, whereas units such as the Ompah Formation have seen all 3 phases. More significantly, in terms of map pattern interpretation, is that the F_1 and F_2 folds produce interference patterns which differ between the different lithologic belts that comprise the synoptic area (*see* Table 5; Photo 36). Furthermore, recognition of fold generation and type (e.g., F_1 synform versus F_2 antiform) is not always possible on the basis of structural style alone (*see* Ford 1992), but typically requires knowledge of the local stratigraphy. Folds lacking Flinton Group strata are particularly difficult to assign to generation. As a consequence, the folds shown on Map P.3443 may differ in generation assignment and type from those shown on the maps of previous workers.

FAULTING

Northwest- to west-trending faults are prevalent throughout the synoptic area (Photo 37; *see* Map P.3443), but are best documented in the Mazinaw and Palmerston Lake areas. Both right- and left-lateral faults with sizable offsets are present: 500 m along the left-lateral fault through Mazinaw Lake; 500 m along the right-lateral Plevna fault; and 500 m along the left-lateral fault running along the west shore of Mosque Lake (*see* Figure 8). Although the existence of this fault set had been recognized previously (e.g., Plevna fault: Smith 1958; Pauk 1987), the abundance of faults of this trend in the area, and the scope of movement along them was previously unknown prior to detailed mapping related to this study (Easton 1994; Easton and Ford 1991; Easton 1992c, 1993).

The age of this fault set is not well constrained. Rotation of the Plevna fault from a westerly trend to a northwesterly trend occurs within the synoptic area. The Plevna fault offsets Paleozoic strata east of the synoptic area, and has generally been regarded as part of the Ottawa–Bonnechere graben (cf. Smith 1958; Williams 1991). This suggests the northwesterly trending faults are related to the Ottawa–Bonnechere graben system. Furthermore, Easton (1992c, 1993) reports an unmetamorphosed diabase dike along a northwesterly trending fault in the Palmerston Lake. This dike is most likely correlative with the Grenville diabase dike swarm, dated at circa 590 Ma (Kamo, Krogh and Kumarapeli 1995), that is related to initiation of the Ottawa–Bonnechere graben. One final piece of age information on the timing of the northwest-trending faults comes from Corfu and Easton (1995), who report a U/Pb age of 599±16 Ma from hydrothermal rutile from the Norway Lake granite adjacent to one of the northwest-trending faults. This age is similar to the age of the Grenville diabase dike swarm reported by Kamo, Krogh and Kumarapeli (1995).

Metamorphic grade rises sharply across the Plevna fault, and it is likely that much of the apparent sinistral and dextral movement along these faults may be the result of vertical, not lateral movement. Williams (1991) documents relative uplift of a few to several hundred metres across some Ottawa graben faults in the Ottawa–St. Lawrence lowlands. Thus, much of the west to east increase in metamorphic grade across the northern Mazinaw domain may be related to vertical movement along these late Neoproterozoic faults, resulting in exposure of a deeper crustal level in northeastern Mazinaw domain.

The economic significance of these faults is unclear. In the Mazinaw area, Easton and Ford (1991) noted the common development of hematite, chlorite, and epidote adjacent to these faults and, in the Palmerston Lake area, epidotization is present at the western end of Sunday Lake along the trace of a west-striking fault. In addition, as described in detail in "Economic Geology", the only 2 areas of significant radioactive mineralization within the synoptic area are spatially associated with these faults. In addition, calcite ± barite ± fluorite ± galena veins are commonly associated with Ottawa graben faults closer to the Ottawa River. The Marlhill calcite mine (Smith 1958; Pauk 1989a) was sited in a calcite vein along the Plevna fault east of the synoptic area.

Metamorphism

The Mazinaw domain has been subjected to at least 2 regional metamorphic episodes. The first, M_1, reaching upper amphibolite and perhaps granulite facies locally, affected all rocks older than the Flinton Group, and was accompanied by intense deformation (D_1) that formed much of the penetrative fabric currently preserved in the rocks. D_1 was accompanied by thrusting and isoclinal folding which formed regional fold structures in the area, and is likely greater than 1160 Ma in age. The second metamorphic event (M_2) affected the Flinton Group, as well as all older rocks, and is circa 1020 Ma in age (Corfu and Easton 1995). The metamorphic pattern in the map area reflects M_2, with greenschist facies conditions (chloritoid-staurolite) present southeast of Marble Lake (550 to 580°C, ~5 to 7 kilobars), rising to upper amphibolite (sillimanite) facies along the northern and eastern boundaries of the synoptic area (670 to 700°C, ~5 to 7 kilobars). Temperature rise from roughly M_2 was accompanied by only localized deformation (shearing, minor folding, refolding of older structures) and was responsible for the growth of randomly oriented porphyroblasts (hornblende, microcline, staurolite, chloritoid, kyanite, tourmaline) in most rock units. Randomly oriented porphyroblasts of white mica are present in many rock units within Mazinaw domain, and likely grew during the waning stages of M_2 metamorphism.

In the field, an observable effect of this multiple metamorphic history is seen when examining fresh surfaces, and is manifested by the absence of well-defined grain boundaries. This is likely due to the fact that during the protracted metamorphic history, large crystals, such as plagioclase, have been recrystallized from large single grains into multi-grain aggregates. When dealing with fine-grained rocks, particularly fine-grained felsic rocks, this recrystallization commonly makes it difficult to distinguish between volcanic, subvolcanic and intrusive rocks. This effect is restricted to rocks older than the Flinton Group, as the Flinton Group was only affect by M_2 metamorphism.

Numerous metamorphic studies have been conducted in the synoptic area, as listed in Table 9, concentrating on the metapelites of the Flinton Group. Despite this large body of work, the metamorphic history of the synoptic area is still incompletely documented and understood.

ISOGRADS AND MINERAL OCCURRENCE ZONES

Several metamorphic isograds, generally defined by the first appearance of diagnostic mineral phases, are present within the synoptic area (Table 10). In addition, large areas of distinctive mineralogy, referred to herein as mineral occurrence zones, are also significant in terms of understanding the regional metamorphic pattern of the synoptic area. Table 10 lists the various isograds and mineral assemblage of zones of significance in the synoptic area, grouped according to rock type. Only those isograds mappable at 1:50 000 scale are shown on Map P.3443.

Table 9. Metamorphic studies within the synoptic area.

Type	Source
Regional	Carmichael, Moore and Skippen (1978); Davidson, Carmichael and Pattison (1990); Rivers (1976); Thompson (1972)
Marbles	Hutcheon (1972); Hutcheon and Moore (1973); Thompson (1973)
Metavolcanic Rocks	Sethuraman (1970); Sethuraman and Moore (1973)
Granitoid Rocks	Chapman (1968); Chapman-Kamilli (1974)
Flinton Group	Finn (1978); Ford (2002); Hounslow (1965); Thompson (1972); Yatabe (1982)

Table 10. Isograds and mineral assemblage zones within the synoptic area.

Rock Type	Isograd	Source
Metavolcanic and Related Calc-Silicate Rocks		
	Chlorite Zone	Sethuraman (1970), Sethuraman and Moore (1973)
	Biotite Zone	Sethuraman (1970), Sethuraman and Moore (1973)
	Blue-Green Hornblende Zone	Sethuraman (1970), Sethuraman and Moore (1973)
	Green Hornblende Zone	Sethuraman (1970), Sethuraman and Moore (1973)
	Diopside Zone	Sethuraman (1970), Sethuraman and Moore (1973)
	Scapolite-Diopside-Hornblende Zone	this study
Metapelitic Rocks		
	Chloritoid-out	
	Staurolite-in	
	Chlorite-Staurolite-out	
	Kyanite-in	
	Staurolite-out (st → gt-sill-bi)	
	Kyanite-Sillimanite transition	
	Plagioclase-in	
	Scapolite-in	this study
	Scapolite-Diopside-Hornblende Zone	this study
	Sillimanite-in (Muscovite-breakdown)	Rivers (1976)
Marbles		
	Tremolite-in	Hutcheon (1972), Hutcheon and Moore (1973)
	Diopside-in?	this study

Table 11. Mineral assemblages present in metavolcanic rocks in the synoptic area.

Zone	Mineral Assemblages
Chlorite	amphibole-oligoclase-chlorite-calcite ± quartz
	amphibole-oligoclase-chlorite-calcite-epidote
	amphibole-oligoclase-chlorite-epidote
Biotite	amphibole-oligoclase-chlorite-biotite-epidote-calcite ± quartz
	amphibole-oligoclase-chlorite-biotite-garnet-calcite-quartz
	amphibole-oligoclase-chlorite-epidote-calcite ± quartz
	amphibole-oligoclase-chlorite-epidote-biotite
	amphibole-oligoclase-epidote-biotite
Blue-green hornblende	hornblende-oligoclase-biotite ± epidote ± calcite ± quartz
Green hornblende	hornblende-anorthite-biotite-calcite ± quartz
	hornblende-anorthite-epidote-calcite-quartz ± potassium feldspar
	hornblende-anorthite-calcite-quartz-garnet
Diopside	hornblende-anorthite-epidote-diopside ± garnet ± quartz ± calcite
	hornblende-anorthite-biotite-quartz ± epidote ± garnet
	hornblende-anorthite-biotite-epidote-quartz-calcite ± diopside
Scapolite-diopside	hornblende-anorthite-diopside-biotite-calcite ± garnet ± scapolite
	hornblende-anorthite-diopside-biotite ± potassium feldspar ± scapolite

Mineral Zones in Metavolcanic Rocks

Sethuraman (1970) and Sethuraman and Moore (1973) recognized 5 mineral assemblage zones within the Tudor and Kashwakamak formation metavolcanic rocks, in order of increasing metamorphic grade: chlorite, biotite, blue-green hornblende, green hornblende and diopside. Mineral assemblages present in these zones are listed in Table 11. Distribution of the zones throughout the synoptic area is illustrated in Figure 20, compiled from data from Ayer (1979), Mannard (1982), Moore and Morton (1986), Pauk (1987) and this study.

Aluminosilicate Isograds

The kyanite-in isograd is first observed in Flinton Group pelites east of Green Bay on Mississagagon Lake, and may be coincident with a northwest-trending fault that is uplifted on the east side (*see* Map P.3443). It is not until the vicinity of Little Mississagagon Lake, however, that large crystals of kyanite are ubiquitous in rocks of the Bishop Corners Formation, and it is possible that the non-uniform distribution of kyanite in the intervening 5 km zone may reflect the results of vertical movement along

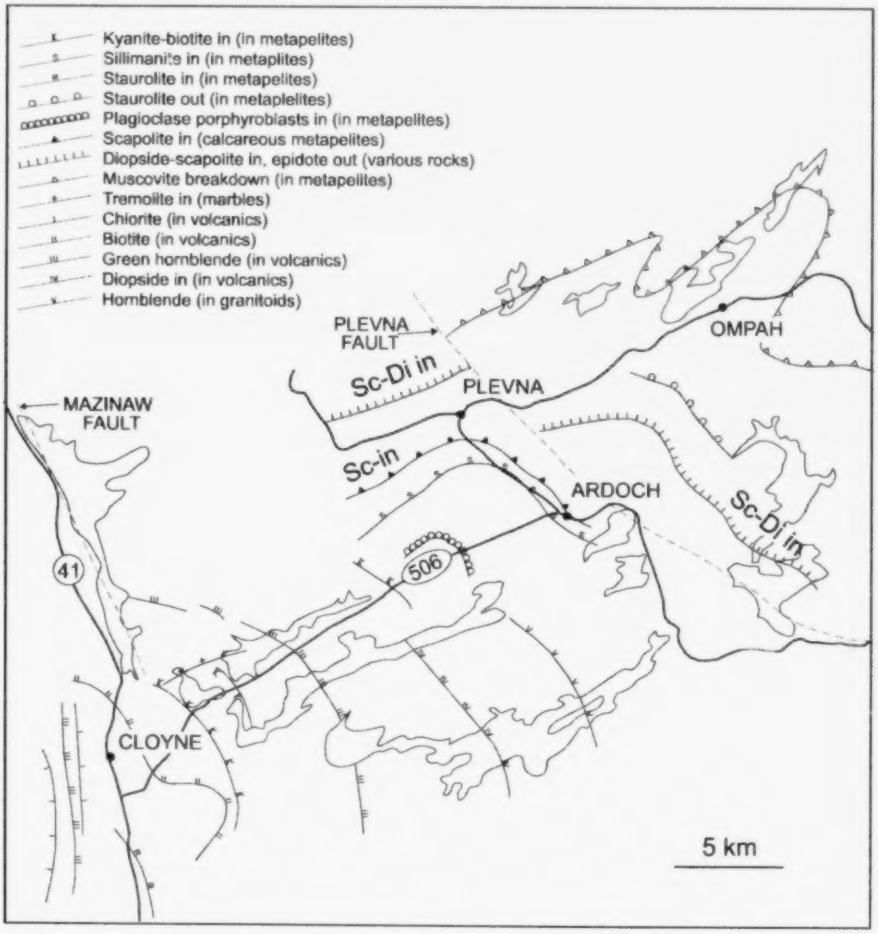

Kyanite-biotite in (in metapelites)
Sillimanite in (in metaplites)
Staurolite in (in metapelites)
Staurolite out (in metaplelites)
Plagioclase porphyroblasts in (in metapelites)
Scapolite in (calcareous metapelites)
Diopside-scapolite in, epidote out (various rocks)
Muscovite breakdown (in metapelites)
Tremolite in (marbles)
Chlorite (in volcanics)
Biotite (in volcanics)
Green hornblende (in volcanics)
Diopside in (in volcanics)
Hornblende (in granitoids)
PLEVNA FAULT
OMPAH
Sc-Di in
PLEVNA
MAZINAW FAULT
Sc-in
ARDOCH
Sc-Di in
41
506
CLOYNE
5 km

Figure 20. Isograds in the Ardoch area, showing relationship of scapolite isograds to aluminosilicate isograds in pelitic rocks.

northwest-trending faults. The sillimanite-in isograd can be traced from Sand Lake to just west of Ardoch. When it first appears, sillimanite may not be readily visible in hand specimen but, in thin section, it can be observed to rim kyanite-grains in kyanite-bearing units such as the Bishop Corners Formation. At higher pressure and temperatures, however, sillimanite becomes readily visible in hand sample of pelitic rock units. In these rocks, kyanite laths may still persist in hand specimen but, in thin section, kyanite has been completely pseudomorphed by sillimanite. Relict kyanite laths locally persist well past the sillimanite-in isograd, and are common in Bishop Corners Formation metapelites in the Mosque Lake area. In the Mosque Lake area, however, fibrous sillimanite is well developed in adjacent pelitic schists of the Myer Cave Formation.

The sillimanite-in or "second" sillimanite isograd is defined by the reaction muscovite + plagioclase + quartz → sillimanite + potassium feldspar. In addition to increasing the sillimanite content of the rock, in the field, the rocks on the high-grade side of this reaction tend to be harder (more difficult to break) and possess a more intragranular or "igneous-like" texture. The location of this isograd is still poorly defined both within and outside of the synoptic area, for 2 reasons. First, in muscovite-rich schists such as the Bishop Corners Formation metapelites, the reaction does not always eliminate all muscovite present in the metapelites, making it easy to pass over the isograd in the field. Second, secondary muscovite overgrowing regional fabrics is common throughout all rock types within the synoptic area, including metaplutonic rocks, again serving to mask the replacement of early formed muscovite by sillimanite in the rocks. Additional field and laboratory work is necessary to better refine the shape and location of this isograd.

Scapolite Isograds

The scapolite-in isograd is newly defined isograd, present within Flinton Group metasedimentary rocks in the Plevna area, and was recognized primarily on the basis of thin section and electron microprobe work. Nonetheless, in hindsight, it is clear that once recognized, this isograd is mappable through field observation, and future mappers should be able to better define this isograd through additional mapping studies. The isograd is observed in calcareous pelites, and probably results from the reaction 3 plagioclase + calcite → scapolite. The reaction is observed at roughly the point where sillimanite begins to form from the destruction of staurolite, and produces calcic (Me82) scapolites. Phase relations in the scapolite system suggests that this occurs at roughly 625°C at 4 to 6 kilobars, similar to the conditions of the bathozone 4/5 boundary reaction (roughly 610°C and 5.5 kilobars). The location of this isograd in pressure–temperature (*P–T*) space is consistent with the distribution of isograds based on aluminosilicate minerals in pelitic rocks.

In addition, a sixth mineral assemblage zone within the metavolcanic rocks is proposed herein, a scapolite-diopside-hornblende zone, located in calcareous metavolcanic rocks and volcaniclastic metasedimentary rocks upgrade from the green hornblende-diopside zone boundary. This combined epidote-out/scapolite-in isograd probably results from a complex reaction process, involving the reaction epidote + hornblende → diopside + plagioclase + calcite and 3 plagioclase + calcite → scapolite. The scapolite-diopside-hornblende zone also appears to lie upgrade from the proposed scapolite isograd present within calcareous metapelites of the Flinton Group, and also appears to be present as a discrete mineral zone within the Fernleigh Formation. The scapolite-diopside-hornblende zone lies downgrade from the muscovite breakdown reaction to form sillimanite (*see* Figure 20). No mineral chemistry is available for scapolites from metavolcanic rocks within the scapolite-diopside-hornblende zone, thus, it is not known if these scapolites are compositionally different from scapolites present within calcareous metapelites of the Flinton Group.

Chemical Controls of Metamorphic Mineral Growth

There may be some geochemical controls on the appearance of certain mineral phases within the various Flinton Group units. For example, kyanite is common in the Bishop Corners Formation in the southeastern part of the synoptic area, but not in the Myer Cave Formation, even though at higher metamorphic grades, coarse fibrous sillimanite is found in both units. It is possible that at lower metamorphic grades, the high carbon content of the pelitic rocks of the Myer Cave Formation serves to inhibit the development of kyanite.

As discussed in the section "Flinton Group", "Geochemistry of the Flinton Group", "Metaconglomerates and Meta-arenites", "Bishop Corners Formation", the composition of the meta-arenites and metapelites reflects the underlying source rocks, such as felsic metavolcanic rocks of the Kashwakamak Formation or meta-tonalites of the Elzevir Suite. The meta-arenites have relatively low SiO_2 contents (69 to 75%), and may have had a high clay component, as suggested by the high total REE contents of the samples. There is no clear correlation between Al_2O_3 content and kyanite abundance in the Bishop Corners Formation (e.g., Hounslow 1965). The combination of high clay content, low carbon content, and possible fine grain size, may all be factors responsible for the preferential development of both kyanite and white mica (muscovite) in the Bishop Corners Formation metapelites.

Thermobarometry

Two samples were studied for thermobarometry. Sample 92RME-0208 is from a pelitic schist from the northeastern part of the synoptic area, near the Mazinaw–Black Donald domains boundary. It is located on the north side of a large belt of tonalitic and granitic gneisses that contain abundant pegmatite bodies. Sample 92RME-1032 is from a garnet-biotite schist of the Myer Cave Formation from the Mosque Lake area. Results are summarized in Table 12.

Temperatures were estimated using the garnet-biotite exchange thermometer of Hodges and Spear (1982), Ferry and Spear (1978), and Indares and Martingole (1985). Data are reported in Table 12 for 2 pressure regimes—4 kilobars and 6 kilobars—as isograd data from the Ardoch area suggests that rocks there are near the bathozone 4 to 5 transition (approximately 5.5 kilobars). Temperature estimates for the 2 samples are relatively pressure insensitive, with temperatures being approximately 5 to 10°C lower at 4 kilobars than at 6 kilobars. Peak temperatures, based on garnet cores and matrix biotite armoured in quartz are in the 690 to 700°C range, and only slightly higher than garnet core-matrix biotite temperatures (650 to 670°C). Calculations based on garnet rim compositions with adjacent biotite at 6 kilobars are lower, 550 to 570°C in sample 92RME-0208 and 580 to 590°C in sample 92RME-1032, and reflect retrograde reactions. In sample 92RME-0208, all 3 calibrations give similar results; however, in sample 92RME-1032, the model 2 calibration of Indares and Martingole (1985) gives temperatures roughly 100°C lower. Even their model 1 calibration gives significantly lower temperatures. Temperatures from both samples overlap, within error, but may be slightly higher for the northernmost sample (92RME-0208).

Table 12. Garnet-biotite thermometry from samples from the synoptic area (this study). All temperatures are in degrees Celsius.

Sample	Hodges and Spear (1982)	Ferry and Spear (1982)	Indares and Martingole (1985), model 2
at 6 kilobars			
92RME-0208-1 (garnet core-matrix biotite)	670	645	654
92RME-0208-2 (garnet core-matrix biotite)	672	648	655
92RME-0208-3 (garnet core-biotite armoured in quartz)	699	674	673
92RME-0208-4 (garnet rim-adjacent biotite)	575	551	572
92RME-1032-1 (garnet inner rim-matrix biotite)	641	629	505
92RME-1032-2 (garnet inner rim-matrix biotite)	634	622	511
92RME-1032-3 (garnet core-biotite armoured in quartz)	693	681	541
92RME-1032-4 (garnet rim-adjacent biotite)	591	584	478
at 4 kilobars			
92RME-0208-1 (garnet core-matrix biotite)	662	637	646
92RME-0208-2 (garnet core-matrix biotite)	663	638	645
92RME-0208-3 (garnet core-biotite armoured in quartz)	691	666	665
92RME-0208-4 (garnet rim-adjacent biotite)	568	543	564
92RME-1032-1 (garnet inner rim-matrix biotite)	633	621	497
92RME-1032-2 (garnet inner rim-matrix biotite)	626	614	503
92RME-1032-3 (garnet core-biotite armoured in quartz)	684	673	532
92RME-1032-4 (garnet rim-adjacent biotite)	583	576	470

Geophysics

AIRBORNE GAMMA-RAY SPECTROMETRY DATA

The synoptic area is covered by 1:250 000 scale regional airborne gamma-ray spectrometric maps (Geological Survey of Canada 1977a, 1977b) in addition to more detailed maps (Ford and Charbonneau 1979; Ford et al. 1992). All gamma-ray spectrometric anomalies for uranium are associated with areas of known radioactive mineralization, mainly in the Crotch Lake and Round Schooner–Reid lakes areas. The relationship between the gamma-ray data, the radioactive mineral occurrences, and additional data such as lake sediment and lake water uranium data is discussed in detail under "Economic Geology", "Radioactive Mineralization".

On the 1:250 000 scale maps, the only patterns that can be related to specific map units are that the highest equivalent potassium and equivalent thorium values occur over the Norway Lake and Abinger granites, although resolution is not sufficient for this to be useful in regional mapping. In contrast, the lowest equivalent potassium values occur over the Kashwakamak and Tudor formation metavolcanics and the marble belts. On the more detailed 1:50 000 scale maps (Ford et al. 1992), the contrast between different rock units is reflected on the gamma-ray spectrometric maps, and the regional pattern of alternating, northeast-trending belts characteristic of the Mazinaw domain is evident. These maps do not show any anomalous patterns that might be associated with areas of alteration, nor do they provide information that can be used to trace contacts in the more poorly mapped parts of the synoptic area.

AIRBORNE MAGNETIC DATA

In addition to the regional total field aeromagnetic coverage over the synoptic area (Geological Survey of Canada 1952a, 1952b, 1952c, 1952d), several detailed surveys have been conducted over parts of the map area. These include a vertical gradient survey over Clarendon Township (centred approximately over Ardoch) (Lechow 1983) and a high-resolution total field and vertical gradient study of the Kaladar–Marmora area (Ontario Geological Survey 1985a, 1985b) that was centred approximately over the Fernleigh belt, and covers parts of the Marble Lake, Mazinaw, Ardoch and Palmerston Lake map areas.

Although some of the gross structure of the area is reflected in the aeromagnetic map patterns, it is difficult to tie the observed magnetic patterns to specific rock units. In part, this is due to the low resolution of much of the current aeromagnetic surveys of the area. Nonetheless, some of the magnetic patterns may be related to regional structures rather than specific stratigraphic horizons, as discussed below. Furthermore, there seems to be a decrease in intensity of the regional anomalies to the northeast, coincident with increasing metamorphic grade, suggesting that the late, high-grade metamorphism (M_2) in the area has caused the breakdown of magnetic-bearing minerals. Nevertheless, a few patterns emerge.

The Northbrook–Cross Lake tonalite and adjacent marbles in the Kashwakamak Lake to Ardoch Lake area are characterized by magnetic lows with broad, low intensity, magnetic contours. Amphibolite belts within the Northbrook–Cross Lake tonalite show up as discrete bands of higher magnetic signature, but overall have intensities lower than that found in the main volcanic belts.

The Harlowe–Mazinaw Lake area is characterized by numerous magnetic highs and closely spaced, high intensity contours. This area coincides with the exposures of metavolcanic rocks of the Kashwakamak and Mazinaw Lake formations. No obvious difference in magnetic signature is apparent between the 2 volcanic formations. In addition, the Norway Lake granite body is characterized by a magnetic high, somewhat higher than the surrounding supracrustal rocks. This is consistent with the magnetite-bearing character of the Methuen Suite granitoids throughout the Grenville Province (Lumbers et al. 1990; Easton 1992b). Although the Norway Lake granite is characterized by a magnetic high, the Abinger Granite shows a very different magnetic signature.

The Abinger Granite consists of 2 different magnetic domains: a 5 to 8 km wide belt of closely spaced contours and magnetic highs in the Mazinaw Lake to Plevna area, that reappears between Mosque Lake and Redhorse Lake, although the highs are more subdued in the northeast; and an 8 to 10 km wide belt that covers the northern two-thirds of the areal exposure of the Abinger Granite that has moderate to low magnetic intensity, and more broadly spaced contours, somewhat similar to the pattern observed for the Northbrook–Cross Lake tonalite. This distribution of magnetic anomalies does not coincide with the relative abundance of tonalite screens within the Abinger Granite, particularly in the Palmerston Lake area where this distribution is well mapped. One explanation is that, in the north, the granitic sheets intruding the older tonalites are relatively thin, and do not contain enough magnetic minerals to affect the regional magnetic pattern. Another explanation, that may partly explain the different magnetic domains within the Abinger Granite, is that higher metamorphic grades were reached in the northern domain resulting in the destruction of the magnetic mineral phases. A second alternative explanation is that the southern belt of the Abinger Granite contains more abundant screens of country rock, particularly of Mazinaw Lake Formation metavolcanic rocks, and that the higher regional magnetic patterns results from these supracrustal rocks. In any case, the magnetic signature of the Abinger Granite does not readily reflect the rock units present within the body and along its margin.

The Fernleigh belt and some of the Flinton Group outliers, such as the Bishop Corners Formation metapelites north of Little Green Lake, are characterized by a lenticular zone of magnetic highs. The magnetic signature of the Fernleigh belt is most apparent where it is adjacent to carbonate and tonalitic rocks of low magnetic intensity, and becomes more difficult to trace magnetically into the Harlowe area and the Donaldson–Sunday Lake area where metavolcanic rocks are more abundant, or adjacent to the magnetic high that characterizes the Norway Lake Granite. As a consequence, magnetic signature is not useful throughout the area to identify Flinton Group versus non-Flinton Group rocks. The magnetic anomalies in the Fernleigh belt appear to be associated with the Bishop Corners and Myer Cave formations metapelites, probably because the Bishop Corners Formation contains abundant magnetite and hematite, and the sulphidic schists of the Myer Cave Formation contain pyrrhotite.

In the Palmerston Lake area, dolomitic marbles on west of Palmerston Lake and along the western margin of the Sunday Lake metavolcanics adjacent to the northern extension of the Fernleigh belt show a lenticular trend of moderate intensity magnetic highs. In fact, in the Palmerston Lake area, this is the only magnetic signature that can be tied to a specific rock unit. It is not known where the magnetic signature might be hosted in the dolomitic marbles, or if the signature reflects underlying units. Alternatively, the trend of anomalies could be an edge effect along the margin of the calcite marble dominated belt that runs northeastward through Palmerston Lake.

An isolated magnetic high of unknown origin occurs directly east of Swamp Lake, in a belt of highly strained paragneisses and marbles, at the west end of the Swamp Creek marble belt. As discussed in greater detail in "Economic Geology", this marble belt shows consistently elevated concentration of Cu and Zn, and this anomaly might be of relevance to mineral exploration in this area. A second more linear anomaly crosses the northern margin of the Swamp Creek belt between the North road and Frontenac County road 506, coincident with an area where several copper assays have been reported. Both anomalies are readily apparent on Figure 5 of Lechow (1983).

Both Lechow (1983) and Pauk (1987) have drawn attention to the magnetic anomaly pattern (lenticular magnetic high) along the north limb of the Plevna synform, which can be traced from Sand Lake to Mosque Lake, and both authors suggested that this anomaly reflects the regional structural pattern. Near Plevna, the anomaly is hosted in sheared paragneisses (metasediments?), and it roughly coincides with the northeast extension of the Shabomeka shear zone. This anomaly is unusual in that it is apparently independent of the map trace, for the most part, of the regional structure as defined by the map units. For example, the anomaly does not define the trace of the Plevna antiform to the north, although Pauk (1987) shows the same lithologic unit being repeated across this fold. Instead, the anomaly continues on strike into the Mosque Lake area, roughly coincident with the belt of Flinton Group rocks near Mosque Lake, and broadening out to include an area of metavolcanic and metagabbroic rocks north and south of Mosque Lake. The anomaly apparently does not reflect regional structure in the Mosque Lake area, although there is difficulty in correlating rock units between the Palmerston Lake and northern Ardoch map areas. Although a magnetic anomaly does persist on the south limb of the Plevna antiform, magnetic intensity of the anomaly decreases dramatically on the south limb. Although a case can be made for a part of the anomaly on the south limb being related to a particularly stratigraphic unit, some other factor must be causing the increase in the amplitude of the magnetic anomaly in the core and the north limb of the Plevna synform. Most likely, this anomaly coincides with the northeastward trace of the Shabomeka shear zone from Sand Lake, through Plevna to Mosque Lake, where it merges with the anomaly in the Palmerston Lake area marking the southern boundary of the Abinger Granite.

A similar problem is apparent in interpreting the aeromagnetic pattern in the Ompah–Sunday Lake area, coincident with the area underlain by the Fernleigh belt, the Ompah structure, and the Sunday Lake volcanics. An aeromagnetic high is associated with this area; however, it is difficult to separate the part of the Ompah structure underlain by Flinton Group strata from the Sunday Lake metavolcanic rocks. In part, this may be due to the derivation, at least in part, of the Ompah Formation rocks from detritus from the Sunday Lake metavolcanic rocks. On the detailed vertical gradient maps, it is possible to separate the Fernleigh belt from that of the Ompah structure, suggesting that the Fernleigh belt is in structural contact with the Ompah structure, as proposed by Ford (1992) on structural grounds.

Other regional fold structures are not readily discerned on the aeromagnetic maps, apart from structure within the Northbrook–Cross Lake tonalite, which is highlighted by the distribution of more highly magnetic amphibolite belts.

The Mazinaw–Black Donald domains boundary in the northernmost part of the synoptic area can be traced roughly on the aeromagnetic maps, and is coincident with a change from the low intensity, broadly spaced contours of the northern Abinger domain to a belt of magnetic highs associated with the amphibolitic rocks common along this contact, particularly from Vennacher to the southern end of Long Schooner Lake. This boundary becomes more difficult to trace magnetically to the northeast, as this amphibolite belt pinches out or is truncated, and marble is in contact with the northern Mazinaw domain.

As noted by Lechow (1983), anomalies located on the north flank of geologic structures in the area coincide most closely with geologic structures (Fernleigh belt, Plevna area anomalies, Mazinaw–Black Donald domains boundary), whereas south-facing anomalies are less readily tied to known structures or lithologic units (with the possible exception of the Norway Lake granite, which also marks the northern limit of the Swamp Lake shear zone). This may be due to the fact that north flank anomalies coincide with north-dipping structures.

The northwest-trending faults present throughout the synoptic area, such as the Plevna fault, have little to no expression on the total field aeromagnetic maps, but are subtly shown on the vertical gradient maps by slight offsets of the linear magnetic anomalies as well as by across fault variations in total magnetic intensity. The Grenville swarm dike located along one of these faults has no apparent magnetic signature, but this may simply reflect the limited width and strike length of the dike relative to the resolution of the aeromagnetic surveys.

In summary, preliminary analysis of the existing aeromagnetic data suggests that the vertical gradient surveys are more useful in discerning particular rock units and structures, particularly northwest-trending faults. With few exceptions, magnetic anomalies do not correlate directly with specific rock units or fold structures, although they may reflect regional shear zones, such as the Shabomeka shear zone and the Mazinaw–Black Donald domains boundary. More sophisticated analysis of the data might be able to determine additional links to the mapped geology of the area. Of interest to exploration are the magnetic anomalies associated with dolomitic marbles in the Palmerston Lake area and magnetic anomalies within the Swamp Creek marble belt.

GRAVITY DATA

Real and Thomas (1987) provide an overview of the gravity data for most of the Central Metasedimentary Belt, including the synoptic area. As previously noted (Easton 1994; Easton and Ford 1994a; Easton and Davidson 1994a), modelled gravity profiles across the Mooroton shear zone show a different profile over the Mazinaw domain, changing from relatively broad and deep (4 to 5 km modelled depth extent) structures, particularly for metaplutons, west of the Mooroton shear zone, to relatively lenticular and shallow (1 to 1.5 km modelled depth extent) under Mazinaw domain. This change is observed on all 4 profiles that cross the Mooroton shear zone (Real and Thomas 1987), and is consistent with regional structural trends within Mazinaw domain and seismic reflection survey data across this boundary (e.g., White et al. 1994; Forsyth et al. 1994).

Economic Geology

MINERAL EXPLORATION

Malczak, Carter and Springer (1985) provided an inventory of base metal, molybdenum and precious metal deposits in the area covered by NTS sheet 31 C (Kingston), which includes the southern two-thirds of the synoptic area. In addition, Geological Data Inventory Folios (GDIF) are available for all townships in the synoptic area, as follows: Abinger (Ontario Geological Survey 1984a), Anglesea (Ontario Geological Survey 1984b), Barrie (Ontario Geological Survey 1984c), Clarendon (Ontario Geological Survey 1984d), Denbigh (Ontario Geological Survey 1984e), Effingham (Ontario Geological Survey 1984f), Kaladar (Ontario Geological Survey 1984g), Kennebec (Ontario Geological Survey 1984h), Miller (Ontario Geological Survey 1984i), North Canonto (Ontario Geological Survey 1984j), Olden (Ontario Geological Survey 1984k), Palmerston (Ontario Geological Survey 1984l) and South Canonto (Ontario Geological Survey 1984m). All these sources were used to create the list of mineral occurrences within the synoptic area shown on Map P.3443.

Barrie Township has had a long history of gold exploration and minor gold production dating back to the turn of the century (cf. Meen 1944; Barron 1983, 1985; Papertzian 1984; Moore and Morton 1986; LeBaron 1991). Barron (1983, 1985) and LeBaron (1991) summarized recent exploration activity in Barrie Township. Many Barrie Township deposits are located near the Flinton Group–Grenville Supergroup unconformity, although the role this unconformity played in siting mineralization is unclear.

Smith (1958) and Pauk (1987) summarized the exploration history of Barrie, and Clarendon and Palmerston townships, respectively. Little exploration activity has been conducted in Abinger, Effingham, Miller, and North and South Canonto townships within the synoptic area. Harding (1944) and (1951) summarized exploration in Kaladar and Kennebec townships, and Olden Township, respectively.

Little exploration has been conducted within the Palmerston Lake area, and may have been discouraged by lack of detailed geologic maps, limited access, and the high metamorphic grade of the area. The only past-producers in the map area are the Summit Lake magnetite deposit, which operated in 1977 and 1978, and a talc deposit east of Mosque Lake, which operated between 1939 to 1941.

ASSAY RESULTS

Field party personnel collected samples for assay from a variety of rock types within the synoptic area, concentrating on the Mazinaw and Palmerston Lake areas. Results are presented in Appendix 2. Data can be grouped into 7 categories, as follows:

1. assays from Flinton Group metasediments
2. assays from gossans in metaplutonic rocks, mainly the Abinger Granite. These gossans show local enrichments of a variety of metals, most notably copper and lead. The discontinuous and narrow nature of these gossan zones suggests that they have limited economic potential.
3. assays from shear zones
4. assays from quartz-tourmaline veins
5. assays from metagabbroic rocks
6. assays of miscellaneous samples
7. assays from the vicinity of the Summit iron mine

Table 13. Tectonic classification of gold "camps" in the Central Metasedimentary Belt (Easton and Kamo 2005).

Age of Mineralization	Name of Camp (*from* Easton and Fyon 1992)	Tectonic Setting
1282 Ma	Bannockburn camp (western Grimsthorpe domain)	Orogenic
~1270 Ma	Not recognized as a separate type, lumped in with Marble Lake–Harlowe camp (Helena intrusion)	Magmatic
~1250 Ma	Cordova Camp	Magmatic
~1250 Ma	Deloro camp	Magmatic, reworked?
>1160 Ma??	Addington–O'Donnell camp (Grimsthorpe–Mazinaw boundary/Flinton Group association)	Orogenic, reworked
>1160 Ma??	Marble Lake–Harlowe Camp (Flinton Group association)	Orogenic, reworked
~1000 Ma	Lavant–Darling camp (Robertson Lake mylonite zone)	Orogenic, young shear zone

GOLD MINERALIZATION

Central Metasedimentary Belt Gold Deposits

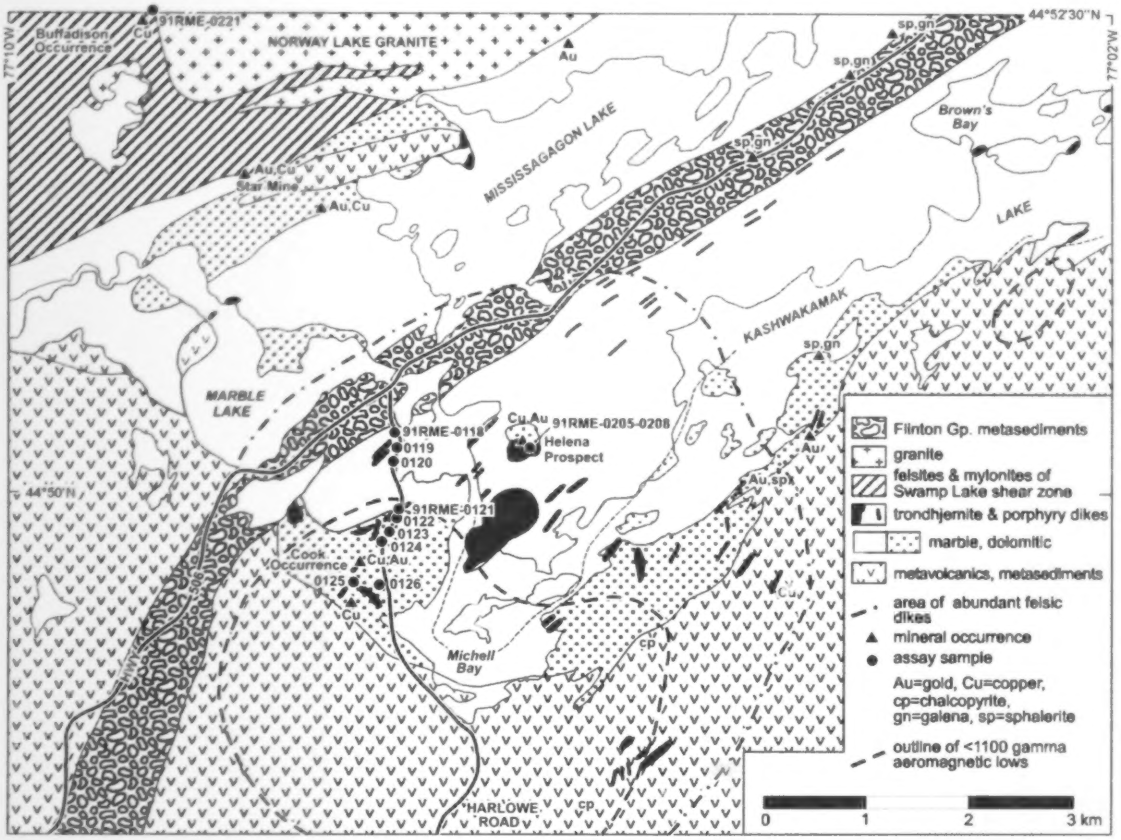
Previous attempts to classify gold deposits in the Central Metasedimentary Belt of the Grenville Province of Ontario (e.g., Carter and Colvine 1985; Easton and Fyon 1992; Sangster and Bourne 1982; Sangster, Gauthier and Gower 1992) have focussed on vein mineralogy and/or host-rock associations, rather than attempting to classify them according to gold deposit models related to modern tectonic settings. Furthermore, there has been a tendency to view the Ontario gold deposits as the product of a single event at a single time or time period. Consequently, the gold potential of the Central Metasedimentary Belt is probably underestimated, with past exploration not necessarily focussed on the areas of highest potential.

Table 13 is a revised classification of the Central Metasedimentary Belt gold "camps", based on age and possible origin of the mineralization. At least 4 broad groupings are present:

- "Orogenic" types are shear-zone hosted systems similar to those observed in Archean greenstone belts. They are typically hosted in metavolcanic sequences, and may be associated with major domain and terrane boundaries.
- "Magmatic" types may be hosted in metavolcanic or carbonate sequences, and are spatially associated with specific mafic or felsic intrusions (e.g., Cordova camp and the Cordova gabbro, Helena camp and Helena trondhjemite stock). These types are more analogous to modern porphyry or manto-type systems.
- A second, unconformity-related, orogenic type exists, hosted in mafic metavolcanic rocks or carbonate rocks, but associated near the unconformity with the metaconglomerates and meta-arenites of the Flinton Group. This association may be analogous to the Archean "Timiskaming-hosted" gold deposits. The age of the second orogenic type is difficult to determine. It is likely younger than the maximum depositional age of the Flinton Group, namely 1160 Ma, but has likely been reworked during 1020 Ma high-grade metamorphism in Mazinaw terrane.
- Finally, gold is associated with mafic metavolcanic, mafic metaplutonic, and carbonate rocks in the late-tectonic Robertson Lake mylonite zone. It is unclear if the gold in this zone is the product of a single gold mineralizing event, or represents reworking of pre-existing gold deposits, or both.

Relationship to Shear Zones

Figure 21 shows the distribution of gold occurrences in the Mazinaw area. All known deposits are located within the Swamp Lake shear zone, and occur in 2 settings. First, gold is hosted in concordant to subconcordant veins in dolomitic marbles of the Grenville Supergroup (e.g., Star Mine, Boerth Mine) or the Flinton Group (e.g., Hardie Property). These veins have tremolite-actinolite reaction rims that have developed along the vein-marble contact (Photo 38), and contain chalcopyrite or tetrahedrite, with minor bornite, sphalerite, pyrite and arsenopyrite. At the Star Mine, chalcopyrite is also disseminated within the marbles. Second, gold is found in crosscutting quartz-tourmaline veins that cut the dolomitic marbles and other lithologies (e.g., Bishop Corners Formation at the Hardie Property; sheared mafic and quartzofeldspathic gneisses at the Star Mine; and sheared granites and dolomitic marbles at the Big Dipper Mine).



77°10'W
44°52'30"N
77°02'W
44°50'N
Buffadison Occurrence
Cu
91RME-0221
NORWAY LAKE GRANITE
Au
sp,gn
sp,gn
sp,gn
sp,gn
Brown's Bay
MISSISSAGAGON LAKE
LAKE
KASHWAKAMAK
Au,Cu
Star Mine
Au,Cu
MARBLE LAKE
91RME-0118
0119
0120
Cu,Au
91RME-0205-0208
Helena Prospect
91RME-0121
0122
0123
0124
Cook Occurrence
Cu,Au
0125
0126
Cu
Au
Au,sp
Cu
cp
cp
Michell Bay
HWY 506
HARLOWE ROAD
Flinton Gp. metasediments
granite
felsites & mylonites of Swamp Lake shear zone
trondhjemite & porphyry dikes
marble, dolomitic
metavolcanics, metasediments
area of abundant felsic dikes
mineral occurrence
assay sample
Au=gold, Cu=copper, cp=chalcopyrite, gn=galena, sp=sphalerite
outline of <1100 gamma aeromagnetic lows
0
1
2
3 km

Figure 21. Distribution of gold and copper occurrences in the southwestern corner of the synoptic area.

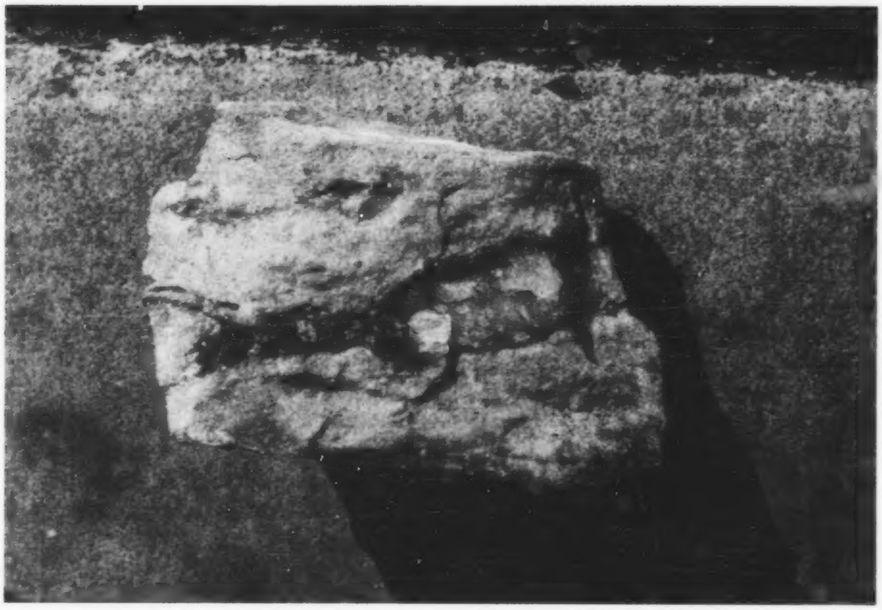


Photo 38. Tremolite-actinolite reaction rims developing along quartz vein-marble contact in sample from the Star Mine. Sample is 12.5 cm wide.

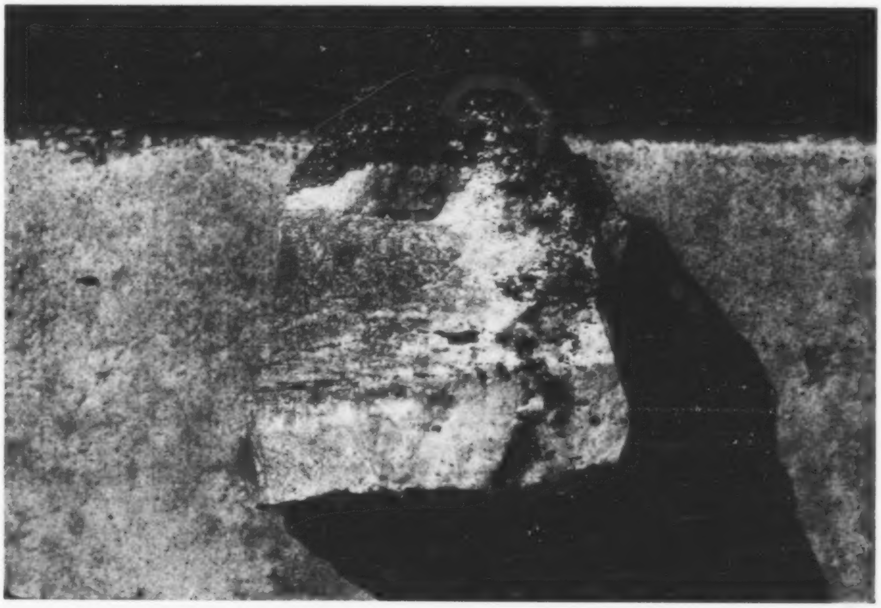


Photo 39. Bleaching of country rock around quartz-tourmaline vein from the Star Mine. Sample is 7 cm wide.

Quartz-Tourmaline Veins

Field observations place some constraints on the timing of intrusion of quartz-tourmaline veins in the area. At the Star Mine, the veins cut sheared felsic gneisses, and have bleached the wall rocks up to 15 cm away from the veins, indicating that the veins are post-M_1 and post-D_1. The felsic gneisses contain recrystallized quartz lenticles, as do the veins, indicating that the veins developed either pre-, or early-syn-M_2. South of Sand Lake, quartz-tourmaline veins cut Flinton Group metaconglomerates and have bleached wall rock around the veins (Photo 39). Furthermore, tourmaline crystals pervade Flinton Group strata adjacent to the veins. Thus, the veins are also post-Flinton Group deposition.

South of Sand Lake, the largest quartz-tourmaline veins (30 to 100 cm wide) are localized at the Norway granite–Flinton Group contact. Also in this area, 2 dominant vein trends are present: 130/70° and 160/75°. Barron (1983) reports concordant quartz-tourmaline veins at the Hardie Property, and that the highest grade mineralization on this property was reported in the quartz-tourmaline veins (5.7 ounces gold per ton). Concordant quartz-tourmaline veins have been observed by field party personnel within felsic gneisses of the Shabomeka shear zone. Wall-rock alteration has not been documented from the concordant veins; however, the concordant veins observed by field party personnel are narrow (<2 cm) and, thus, such alteration may be poorly developed. The wide range in vein types and vein thickness suggests that the veins followed existing weakness in the rocks, and were not influenced by a regional stress field. The M_2 stress field was isotropic as demonstrated by porphyroblastic minerals in Grenville Supergroup and Flinton Group rocks. Assays from some quartz-tourmaline veins in the area are reported in Appendix 2.

Association with Flinton Group

Both vein types at the Hardie Property are hosted in Flinton Group strata. The Star Mine is hosted in deformed Grenville Supergroup strata, and is about 1 km from the nearest exposures of Flinton Group rocks. The Big Dipper Mine is hosted in sheared rocks at the southern margin of the Norway Lake granite, about 500 m south of a Flinton Group metaconglomerate and metapelite belt. The Boerth Mine is hosted in deformed Grenville Supergroup rocks; however, it, too, is only a few hundred metres distant from Flinton Group outcrops. It is difficult to assess the significance of the proximity of the deposits to the Flinton Group unconformity. Did the existence of a pre-existing shear zone influence deposition of the Flinton Group and, thus, the association is only coincidental? Or did the unconformity surface focus fluid flow during reactivation of the shear zone during Flinton Group deposition and subsequent metamorphism, thereby localizing gold-bearing quartz-tourmaline veins in basement and cover rocks located near the unconformity?

South of the synoptic area, along Flinton Creek and in the Harlowe area, gold deposits are also associated with the Flinton Group unconformity. The Dome occurrence is hosted in concordant quartz veins hosted in Grenville Supergroup dolomitic marbles immediately underlying the Bishop Corners Formation. Flinton Group strata in this area probably overlie an older shear zone developed in underlying mafic metavolcanic rocks. At the Addington Mine, Bishop Corners Formation metaconglomerates unconformably overlie an older shear zone developed in mafic metavolcanic rocks. In this instance, carbonate rocks are not present, suggesting that the presence of dolomitic marbles may not be a critical factor in siting gold mineralization. Rather, the existence of an older shear zone with overlying Flinton Group rocks is probably the key factor.

Metamorphic Grade

Apart from the Boerth Mine, and the James and Webber properties to the northeast (*see* Figure 21), most gold deposits present in the map area, and to the south, are located near the greenschist–amphibolite facies transition.

Guidelines for Gold Exploration

Gold deposits in the map area are associated with the shear zones developed in pre-Flinton Group strata in the area. Historic occurrences are commonly hosted in dolomitic marbles present within or adjacent to the shear zones. Gold is also found in quartz-tourmaline veins cutting both basement and Flinton Group rocks in proximity to the shear zones, and the largest veins are located near the unconformity surface Flinton Group. To date, all occurrences in the map area are localized in the Swamp Lake shear zone, particularly in the lower metamorphic grade segment of it. It is not known if the lack of occurrences along the Shabomeka shear zone reflects lack of exploration, the lack of dolomitic horizons within the shear zone, the paucity of Flinton Group strata along the shear zone, or higher metamorphic grade, or some combination of one or more of these factors.

INDUSTRIAL MINERALS

Building Stone

No building stone prospects have been documented from the synoptic area, nor have any quarries operated within the map area (LeBaron et al. 1989).

Calcite Marble

Within the Black Donald domain, Bancroft Terrane, coarse-grained, white, calcite marbles containing less than 5% impurities occurs in cliffs along the western shore of Long Schooner Lake (343910E 4996390N). Thin section examination indicates fine-grained apatite and oxides are the main impurities, as does a chemical analysis (*see* Appendix 1, sample 92RME-0140).

Marl

Mair Lake is a previously undescribed marl lake.

Mica, Sillimanite and Kyanite

Two sites within the synoptic area have been evaluated for mica or sillimanite extraction; both are located within the Bishop Corners Formation metapelite of the Flinton Group. The best known of the 2 sites is the Clarendon Township sillimanite occurrence, located near Little Green Lake, in an outlier of Bishop Corners Formation metapelite, located north of the Fernleigh belt, overlying Grenville Supergroup marbles and minor paragneiss. The geology of the occurrence is described by Black and Rencz (1988).

Average mineral content of the unit is 24.6% sillimanite, 5.6% garnet and 46% mica (Lakefield Research 1990). Several separation techniques were tested on samples from this site, including gravity and magnetic separation and flotation. No single method was effective in separating sillimanite and garnet from micas in the deposit (Lakefield Research 1990). Further development awaits a satisfactory means of separating sillimanite and muscovite. Either mineral is sufficiently abundant to be a commercial product from this occurrence.

The second site is located between Fernleigh and Swaugers Lake within the Fernleigh belt, a strike length of roughly 3 km. This occurrence is also hosted in metapelite of the Bishop Corners Formation. The site was investigated in 1981 by Trisar Resources Limited, and was mapped in detail by Yatabe (1982). In this area, garnet, staurolite, kyanite and sillimanite form porphyroblasts in the metapelite, the exact mineralogy varying with respect to the general eastward increase in metamorphic grade. In the western part of the study area, Yatabe (1982) reports modal muscovite contents ranging from 28 to 81%. Muscovite contents were not reported from the detailed study area due west of Swaugers Lake, which Yatabe (1982) suggested could be developed as a potential mica deposit, although porphyroblast content (staurolite, kyanite, biotite) was reported. As a consequence, the relative merits of this site with respect to the Clarendon sillimanite occurrence cannot be directly evaluated.

Other sites of interest for muscovite and aluminosilicate mineralization include

1. At the east end of Little Mississagagon Lake, about 500 m west of the area studied by Yatabe (1982), Hounslow and Moore (1967) analyzed a metapelite containing 42% modal muscovite. In fact, the bulk chemistry of this sample approximates the average composition of muscovite (Hounslow and Moore 1967, their analyses 7a). This sample also contains 19.2% modal kyanite, and 5.3% garnet, closely approximating the composition of the schists at the Clarendon sillimanite occurrence.
2. The Mosque Lake area hosts both coarse-grained nodular sillimanite-garnet schists and muscovite-sillimanite (after kyanite) schists, hosted within Myer Cave Formation and Bishop Corners Formation metapelites, respectively. This area should be further investigated for aluminosilicate-garnet or mica potential.
3. Storey and Vos (1981b) described a mica occurrence near Turcott Lake, northeast of Ompah, also hosted within metapelite of the Bishop Corners Formation. This site only contains approximately 10 to 15% muscovite, and is not obviously any more micaceous than other Bishop Corners Formation metapelites in the Ompah to Canonto area.

On the basis of regional metamorphic grade, metapelites of the Bishop Corners Formation in the area between Little Mississagagon Lake and Canonto hold the best potential for mica and aluminosilicate minerals, with kyanite being most abundant west of Ardoch, and sillimanite to the west. Sillimanite is also abundant in Myer Cave Formation metapelites in the Ompah to Canonto area, however is typically associated with garnet and biotite.

Tremolite and Talc

Several dolomite and tremolite prospects occur in the northern Ardoch and the Palmerston Lake map areas. A 300 to 500 m wide belt of coarse-grained white dolomitic marbles, with layers, pods and segregations of coarse-grained, white to pale-green tremolite (Photo 40) and diopside occurs along the southwest shore of Palmerston Lake (UTM ~352700E ~4985400N), and has a strike-length of at least 2 km. This zone probably represents the higher metamorphic grade equivalent of a belt of pure, blue-grey dolomitic marbles present within the Ardoch map area traceable from Plevna to Palmerston Lake (LeBaron and MacKinnon 1990). LeBaron and MacKinnon (1990) report analyses of the lower grade

Photo 40. Large tremolite clots in marble on the northwest shore of Palmerston Lake. Scale card marked in centimetre intervals.

Photo 41. Pit (left of tree in foreground) and dump (right of tree) developed in metasomatic iron skarn deposit located south of Sand (Plevna) Lake (UTM Zone 18, 340870E 4975780N, NAD27).

dolomites indicating high-purity and low brightness. The high-grade equivalents are much whiter than the low-grade rocks, and it is likely that brightness is higher than in the low-grade rocks. Thin section examination and chemical analyses of these high-grade rocks (*see* Appendix 1, samples 92RME-0049 and 92RME-0061) indicates high-purity (<2% impurities). This belt has the potential of producing high-purity and brightness dolomite, and possibly tremolite and diopside from the same site.

Within the Palmerston Lake area, Smith (1958) described a talc deposit southeast of Mosque Lake (UTM 350610E 4986055N) that operated between 1939 and 1941. Although described as a talc schist, the host rock consists of a belt of calc-silicate, dolomite, and tremolite, with local development of talcose zones. LeBaron and van Haaften (1989) show a sketch map of this deposit showing the location of 5 prospect pits and 2 shafts on the property. Subsequent to their study, additional exploration was conducted on this property by parties unknown, in the form of 3 trenches dug perpendicular to strike of the talc-dolomite unit across pits 2, 3 and 4, and in a talc-tremolite band located 150 m to the north (UTM 350600E 4986150N). A grab sample from the northern trench collected by field party personnel consisted entirely of pale green to white tremolite. This talc-tremolite-dolomite band extends through Mosque Lake, and is offset along a northwest-trending fault. The talc-tremolite-dolomite belt is isoclinally folded, overturned to the north, and plunges to the east. On one island in the centre of Mosque Lake, talc-serpentine schist is present (UTM 349250E 4985440N). On an island at the extreme west end of Mosque Lake (UTM 348380E 4985520N), field party personnel located an area of pure, white to pale green talc schist. These observations suggest that the purest and highest grade talc deposits may be located in and under Mosque Lake, and that the previously operated deposit is located in a poor quality part of the talc belt.

Within the Mazinaw Lake area, relatively pure dolomite marble occurs along the north (UTM 339275E 4977100N) and south shore (LeBaron and MacKinnon 1990) of Sand Lake (*see* Appendix 1, sample 91RME-0002). Within the Palmerston Lake area, coarse-grained, white, high-purity dolomite marble occurs east of Sunday Lake (UTM 361720E 4987725N) (*see* Appendix 1, sample 92RME-1055).

IRON MINERALIZATION

Magnetite Skarn Mineralization

A skarn is developed within a contact aureole developed around the northern tip of the Norway Lake granite where the granite intrudes calcitic marbles (*see* Figure 15). The skarn zone extends for 500 to 750 m outward from the granite contact, and consists of a fine-grained diopside-epidote-plagioclase-calcite rock, which locally contains large randomly oriented porphyroblasts of garnet or tourmaline that grew during M_2. The skarn zone is locally unconformably overlain by Flinton Group metapelites. Mineralization in the skarn zone consists of a contact metasomatic iron deposit, which has been trenched. The trench measures 2 by 5 by 3 m, and a sizable dump is present (Photo 41). No assessment work is available on this deposit (Assessment Files Research Office, Toronto, and Southeastern Resident Geologists Office, Tweed). Sample 91RME-0170 (*see* Appendix 2) is from the dump. Samples 91RME-0171 and 91RME-2133 (*see* Appendix 2) are from skarn rocks. This is one of the few contact metasomatic skarn deposits known from the Mazinaw domain (cf. Carter 1984; Easton 1992b).

The Summit Lake (or Tomclid) magnetite iron mine (UTM 354730E 4990100N), in the Palmerston Lake area, was operated from 1977 to 1978 by TMF Resources, producing magnetite concentrate for high-density aggregate in concrete containment shields for nuclear reactors, with waste rock used as road fill. The deposit contains at least 1 200 000 tonnes of ore (Carter, Colvine and Meyn 1980). Production was restarted in 1997 when 12 000 tonnes of 25% magnetite were extracted to meet a contract with

Table 14. Assay samples collected from the Summit iron mine.

Sample Number	Easting (m)	Northing (m)	Fe (wt. %)	TiO_2 (wt. %)	P_2O_5 (wt. %)	V (ppm)	La (ppm)	Ce (ppm)	Nd (ppm)	Comment
92RME-0030A	354730	4990100	59.8	0.52	0.07	136	27	46	16.4	Fine-grained crushed ore from pile at mine site
92RME-0030B	354730	4990100	79.3	0.30	<0.05	128	2.5	4.6	2.1	Magnetite ore from tailings dump

All samples analyzed by the Geoscience Laboratories, Ontario Geological Survey, Sudbury. Rare earth element values represent minimum values, because residue was left in beakers after dissolution of the samples, indicating incomplete dissolution. UTM co-ordinates are provided in NAD27, Zone 18.

Ontario Power Generation. Operations have continued on an as-needed basis, currently by Coloured Aggregates Incorporated. Surface stripping around the deposit provides spectacular exposures of both the ore zone and the host rocks. The composition of 2 grab samples of the ore at the Summit Lake iron mine are presented in Table 14.

Massive magnetite mineralization at the Summit Lake iron mine is hosted in clinopyroxenite and gabbro. The clinopyroxenite appears to be hosted in a recrystallized shear zone consisting of fine-grained, white to pink weathering quartzofeldspathic gneisses. The shear zone lies along the southeastern edge of a large area of gabbro and gabbroic gneisses, both locally garnetiferous. The clinopyroxenite is altered to a coarse-grained grossularite-diopside gneiss; this alteration generally occurs in a zone 50 to 250 m distant from the magnetite ore. Carter, Colvine and Meyn (1980) regarded the mine as a skarn deposit; however, marbles and calc-silicate rocks are not found near the deposit. The deposit, however, is locally cut by calcite veins. Many skarn deposits are zoned, with magnetite abundant near the heat and fluid source, grading outward into garnet endoskarn and, finally, pyroxene endoskarn. If the Summit Lake iron mine is indeed a skarn, then potential for copper-gold mineralization may occur within the pyroxene endoskarn, which lies beyond the mine property.

On the other hand, ultramafic pods and oxide mineralization occur in gabbroic rocks of the Killer Creek Gabbro Suite (Easton 1992b) at lower grade and at a similar stratigraphic level to the southwest in the Mazinaw area; consequently, it is possible that this deposit represents a metamorphosed magmatic deposit. The complex deformational and metamorphic history renders any conclusions on the origin of this deposit equivocal. The Summit Lake deposit was discovered by the use of aeromagnetic surveys (Carter, Colvine and Meyn 1980), and it is noteworthy that the deposit is not clearly evident on the regional aeromagnetic map of the Clyde Forks area (Geological Survey of Canada 1952c). Consequently, undiscovered deposits of similar-size could be present in the Palmerston Lake area, and at the same stratigraphic level to the southwest.

Smith (1958) and Carter, Colvine and Meyn (1980) described a magnetite deposit on the southeast shore of Longstone Lake near a marble–paragneiss contact. Field party personnel could not locate this deposit, which apparently was originally prospected prior to 1909. This deposit is roughly on strike with the Summit Lake iron mine.

Magnetite and Chromite in Metagabbroic Rocks

Easton and Ford (1990) reported enrichments in magnetite and chromite in rocks of the Killer Creek Gabbro Suite, particularly the hornblendite and melanocratic gabbro phases. Equivalents of this suite in the Mazinaw domain are similarly enriched in these elements. The most significant accumulation is located due west of the synoptic area, northeast of Joeperry Lake in Bon Echo Provincial Park, where a significant aeromagnetic high (Geological Survey of Canada 1952a) is underlain by a body of melanocratic metagabbro of the Killer Creek Gabbro Suite containing abundant hornblendite pods. Assay sample 91RME-0060 (*see* Appendix 2) is from one of these pods, and shows elevated concentrations of chromium and vanadium. The high titanium content of the Killer Creek-type gabbros suggests the presence of ilmenite as well. The Joeperry Lake metagabbro has a fine-grained phase of chlorite-hornblende-magnetite around its margins, which may be the product of metamorphic reaction related to fluid interaction with surrounding rocks during M_2. This magnetite-rich rim may be largely responsible for the intense aeromagnetic signature of this body, which is atypical of the suite elsewhere in the Grimsthorpe domain or the Mazinaw domain.

Field party personnel located an area of compass unreliability approximately 350 m in diameter on the north-central shore of Redhorse Lake (centred at UTM 358725E 4995000N) hosted in a deformed, Killer Creek Suite type gabbro-anorthositic-hornblendite body. This anomaly may represent a magnetite deposit associated with the hornblendite phase of the deformed pluton.

RADIOACTIVE MINERALIZATION

Mazinaw domain differs from adjacent terranes and domains in containing several radioactive mineral occurrences. These occurrences are clustered in 3 main areas, namely, the Kaladar–Sheffield area, the Crotch (Cross) Lake area, and the Round Schooner–Reid lakes area . The latter 2 areas lie within the synoptic area, and both were actively explored in the mid- to late-1970s, as summarized in Pauk (1987) and Masson and Gordon (1981), respectively. All areas are identified on regional airborne gamma-ray spectrometric anomaly maps (Geological Survey of Canada 1977a, 1977b; *see also* Ford and Charbonneau 1979) and the 2 areas within the synoptic area have associated lake sediment or lake water uranium anomalies (Croker and Closs 1979; Ontario Geological Survey–Geological Survey of Canada 1977a, 1977b). The Mazinaw domain radioactive occurrences differ from Bancroft area radioactive occurrences in having higher regional equivalent uranium–equivalent thorium (eU/eTh) values (0.50 to 0.75 in Mazinaw domain versus <0.50 in Bancroft terrane) and lower regional equivalent thorium values (<5 ppm in Mazinaw domain versus 5 to 10 ppm in Bancroft terrane), even though both areas have similar maximum equivalent uranium values (>3 ppm)(Ford and Charbonneau 1979; Ford 1982). Marek et al. (1983) conducted a scintillometer survey of the Flinton Group in the synoptic area and found no significant difference in radioactivity between the Flinton Group and adjacent rock units, consistent with the lack of radioactive mineral occurrences within the Flinton Group.

Pauk (1987) reported 3 major types of pegmatite occurrence in the Crotch (Cross) Lake area:

1. as stratabound pegmatites intruded along foliation planes, generally in mafic metavolcanic rocks or paragneisses
2. as crosscutting pegmatites intruding gneissic host rocks, with trends of 120 to 150°
3. as irregular, commonly sinuous and discontinuous, bodies and swarms of pegmatites, confined to metatonalitic gneisses of the Cross Lake–Northbrook pluton and granitic gneisses of the Addington granite

Mineralized pegmatites in the Round Schooner–Reid lakes area are type 2. Type 2 pegmatites also occur within the Palmerston Lake area cutting marbles; however, none of these pegmatites are known to contain radioactive mineralization.

Ford (1982) reported that most pegmatites in the Crotch (Cross) Lake area are leucocratic, white to pale pink, and monzogranitic in composition, although red varieties do exist. Similar observations were made by the author in the Round Schooner–Reid Lakes area (Palmerston Lake map area). Pauk (1987) suggested that the pegmatites hosted in metavolcanic rocks had greater mineral potential, in part because of larger size. Ford (1982) studied pegmatites in the same area, and suggested that pegmatites hosted in Grenville Supergroup gneisses had higher average equivalent uranium values (29 to 41 ppm) than pegmatites hosted by metaplutonic rocks or Flinton Group metasedimentary rock (3 to 8 ppm), in agreement with Pauk's (1987) suggestion. Ford (1982) also reported high equivalent uranium values within sheared, biotite-rich zones in the pegmatites. On the basis of this rationale, the Crotch (Cross) Lake area would have greater mineral potential than the Round Schooner–Reid lakes area.

Masson and Gordon (1981) described 3 occurrences and a minor occurrence from Miller Township in the Wensley area. None of these occurrences were visited by the author. The Whytock occurrence had been described previously by Satterly (1971), who reported that feldspar had been mined from this site in 1954–1955, and that only minor radioactive mineralization was detected. Croker and Closs (1979) reported little geochemical expression for uranium in lake waters or sediments near these occurrences and suggest that these occurrences are of minor economic significance. This is consistent with the weak airborne gamma-ray expression of the Wensley area occurrences compared to the Round Schooner–Reid lakes occurrences in the Palmerston Lake area (Geological Survey of Canada 1977a). The Whytock occurrence is significant in that it is one of the few Central Metasedimentary Belt pegmatites having slightly anomalous chemistry with respect to rare element potential (Goad 1990), as indicated by low K/Cs and K/Rb ratios. Although Goad (1990) states that these anomalous pegmatites are not likely to produce significant amounts of rare elements (Cs, Li, Rb, Nb, Ta, Sn, Be), they may contain undeveloped mineral collecting potential.

Airborne gamma-ray spectrometric maps of the area (Geological Survey of Canada 1977a) show 2 areas of radioactive mineralization in the Palmerston Lake area, the largest of which is located southeast of Reid Lake. The other is located northeast of Round Schooner Lake. Masson and Gordon (1981) describe exploration activity and occurrences from both areas. Southeast of Reid Lake, uranium and thorium mineralization is associated with a large area of granite pegmatite dikes, commonly containing smoky quartz, which intrude tonalite orthogneiss. South of South Quinn Lake is a large area of granite pegmatite outcrop; however, it is not anomalous in uranium or thorium on the gamma-ray maps. All of these pegmatites were explored in 1969 and 1976 to 1977, according to Masson and Gordon (1981), with the highest mineralization being reported from the Bordun occurrence (1.4% Th; 3800 ppm U_3O_8, UTM ~349680E ~4990710N). Field party personnel located several trenches and diamond-drill holes related to this previous exploration activity, as illustrated on Map P.3335 (Easton, Ford and Cooke 1995).

In the Round Schooner Lake area, Masson and Gordon (1981) reported radioactive mineralization from several granite and diorite pegmatite dikes intruded into marble of the Black Donald domain. These dikes, first explored in 1954, are small and not as abundant as in the Reid Lake area. The highest assay values reported by Masson and Gordon (1981) were 490 ppm U_3O_8 and 390 ppm Th.

Field party personnel located a series of trenches in granite pegmatite dikes intrusive into granitic and tonalitic gneisses on the south shore of Long Schooner Lake (UTM ~345350E 4996000N) (Easton, Ford and Cooke 1995) for which no previous exploration activity has been described. Based on the degree of revegetation, these pits appear to date from the mid-1970s. Scintillometer readings were only slightly higher than background, and no significant mineralization was noted at these trenches by the author.

Both the Round Schooner and Reid Lake radioactive mineral occurrences are located near northwest-trending faults and, given the fact that pegmatite dikes occur throughout the Palmerston Lake map area, this spatial association may be significant. Masson and Gordon (1981) reported the highest mineralized values in sheared, biotite-rich rocks, and it is possible that late-stage fluid-movement related to these faults may have served to remobilize and concentrate pre-existing radioactive mineralization, similar to the Paleozoic-hosted South March occurrence (*see* Masson and Gordon 1981, p.94).

Ford (1982) suggested that the pegmatites formed as the result of anatexis of selected Grenville Supergroup paragneisses. This mechanism is consistent with the observation from the synoptic area that the areas of greatest pegmatite abundance are found in the areas of highest metamorphic grade. It is unclear, however, if the three pegmatite emplacement modes represent 3, temporally discrete, pegmatite emplacement events, or whether they are simply different manifestations of the same anatextic event, with the differing intrusive relationships simply reflect heterogeneous deformation across the synoptic area during emplacement. Corfu and Easton (1995) sampled for geochronology 2 non-mineralized pegmatites intruding tonalitic gneisses in the Granite Lake area (Palmerston Lake map area). Ages of 1079±2 Ma and 1063±5 Ma were obtained from an undeformed, crosscutting pegmatite (type 2) and a protomylonitic, foliation parallel pegmatite (type 3), respectively. These ages are older than typical ages from Bancroft area pegmatites (cf. Easton 1986a, 1992b). In contrast, muscovite-plagioclase-quartz pegmatites cutting the Flinton Group gave a zircon age of 984±4 Ma (Corfu and Easton 1995). Pink to red, massive pegmatite dikes (type 2) that intruded marbles at Palmerston and Canonto lakes have not had ages determined. The limited data suggest that more than one age of pegmatite may occur within the synoptic area, but, whether radioactive mineralization is restricted to a particular age of pegmatite generation is unknown.

SULPHIDE MINERALIZATION

Volcanogenic Massive Sulphide Mineralization

Within the Superior Province in Ontario, most VMS deposits are associated with a distinctive suite of rhyolites, termed FIII rhyolites (e.g., Lesher et al. 1986), and P_2O_5-rich andesite flows and sills termed icelandites (e.g., Lesher et al. 1986; Fyon et al. 1992). Although the presence of such rocks in the Grenville Province was alluded to by Easton and Fyon (1992), their distribution and stratigraphic relationships with other volcanic sequences remained uncertain. Easton and Ayer (1994) documented that the Mazinaw Lake Formation consists of an icelandite-FIII rhyolite suite; consequently, this formation may host volcanogenic massive sulphide mineralization.

Geochemical data collected during the course of this study confirm the earlier major element work of Ayer (1979) on the Mazinaw Lake Formation, and allow discrimination of metavolcanic rocks of the Kashwakamak and Mazinaw Lake formations. The rare earth elements clearly illustrate these geochemical differences (*see* Figure 2). Intermediate to felsic metavolcanic units from the Kashwakamak Formation (only one typical sample is shown in Figure 11a for clarity) show calc-alkalic trends, similar to results obtained from this unit by Condie and Moore (1977) and Harnois and Moore (1991) (*see* Figure 10). Figure 11a also shows data from andesitic (sample 91RME-0021) and rhyolitic (sample 93RME-0014) metavolcanics of the Mazinaw Lake Formation. Sample 93RME-0014 (*see* Figure 11a) is well preserved, whereas sample 91RME-1023 is highly sheared (*see* Figure 11a). Figure 11b shows data obtained from coeval, fine- to medium-grained syenogranite bodies intrusive into the Mazinaw Lake Formation. The rare earth element patterns from the intrusive rocks are identical to those obtained from the corresponding metavolcanic rocks. Sample 94RME-0190 (*see* Figure 11b) is a granite cobble from the Flinton Group adjacent to the Norway Lake granite (*see* Figure 11b, samples 91RME-0234 and 93RME-17), and indicates that the Flinton Group metaconglomerates include locally derived detritus.

As shown in Figure 11, rare earth element patterns of the Mazinaw Lake Formation metavolcanics are similar to FIII rhyolites from the Superior Province, such as those from the Kamiskotia area, Abitibi greenstone belt. Lesher et al. (1986) proposed 2 subdivisions of FIII rhyolites, with FIIIb rhyolites characterized by slightly higher SiO_2, lower TiO_2 and total Fe contents, and low Zr/Y ratios (2 to 6) than FIIIa rhyolites. The Mazinaw Lake Formation metavolcanics are of the FIIIa type. Icelandites are also present and, in the Cloyne area, are massive, medium-grey weathering rocks commonly containing magnetite + garnet porphyroblasts. Re-examination of the major element data of Ayer (1979) (*see* Figure 11c) indicates that icelandites form of the bulk of the mafic metavolcanic rocks of the Mazinaw Lake Formation.

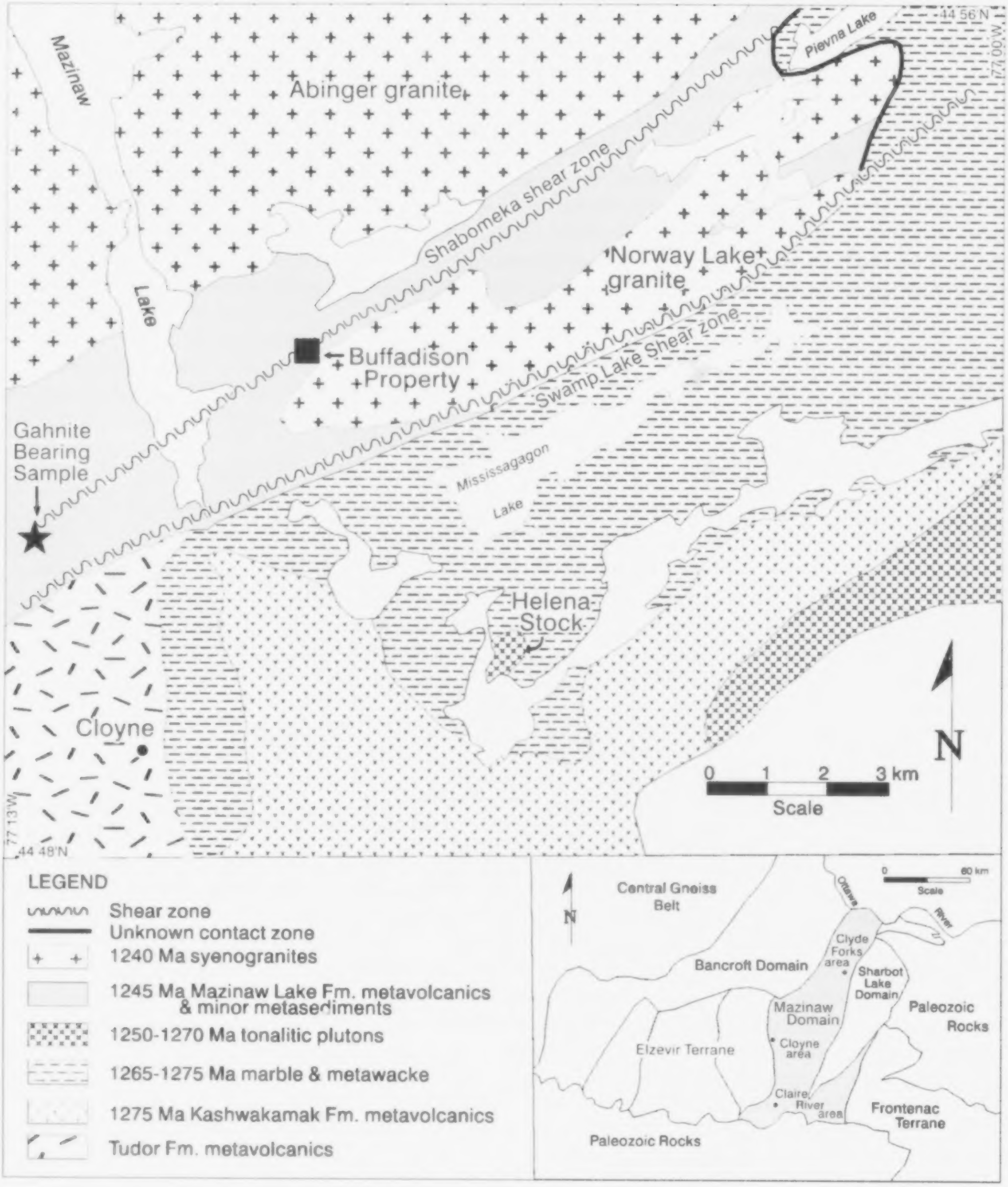

Mazinaw
Lake
Abinger granite
Shabomeka shear zone
Pievna Lake
44 56'N
77 00'W
Norway Lake granite
Buffadison Property
Swamp Lake Shear zone
Gahnite Bearing Sample
Mississagagon
Lake
Helena Stock
Cloyne
0 1 2 3 km
Scale
N
77 13'W
44 48'N
LEGEND
Shear zone
Unknown contact zone
1240 Ma syenogranites
1245 Ma Mazinaw Lake Fm. metavolcanics & minor metasediments
1250-1270 Ma tonalitic plutons
1265-1275 Ma marble & metawacke
1275 Ma Kashwakamak Fm. metavolcanics
Tudor Fm. metavolcanics
Central Gneiss Belt
0 60 km
Scale
Ottawa
River
N
Clyde Forks area
Bancroft Domain
Sharbot Lake Domain
Mazinaw Domain
Paleozoic Rocks
Elzevir Terrane
Cloyne area
Claire River area
Frontenac Terrane
Paleozoic Rocks

Figure 22. Distribution of Mazinaw Lake Formation metavolcanic rocks in the southwestern corner of the synoptic area, showing the location of the Buffadison property and the gahnite-bearing modern alluvium sample.

CLOYNE AREA

Given the strong spatial association of FIII rhyolite and icelandites with VMS deposits in the Archean, the presence of this same rock association in the Cloyne area makes this area a favourable target for VMS exploration. The Mazinaw Lake Formation is areally restricted (Figure 22), and Ayer (1979) suggested that a volcanic centre was present within the Mazinaw Lake Formation at the south end of Mazinaw Lake (*see* Figures 5 and 20; *see* Map P.3443). The gahnite-bearing modern alluvium sample reported by Felix, Reid and Easton (2006) lies along the western edge of this volcanic centre (*see* Figure 22).

Little exploration has been conducted within the Mazinaw Lake Formation in Barrie Township, compared to the area underlain by the Kashwakamak Formation. The only known sulphide occurrence within the Mazinaw Lake Formation is the Buffadison property (occurrence 6, Map P.3443), explored by Buffadison Gold Mines in 1959. Mineralization consists mainly of chalcopyrite, pyrite, bornite, chalcocite and covellite sealing fractures within metavolcanics. The property is now largely overgrown. Moore and Morton (1986) related the mineralization at Buffadison to a nearby diorite body; however, whether there is a genetic link is tenuous (Easton and Ford 1991). Exploration should focus on the Mazinaw Lake–Shabomeka Lake area where the volcanic pile is most extensive.

MAZINAW DOMAIN

Possible equivalents of the Mazinaw Lake Formation metavolcanics may occur elsewhere in the Mazinaw domain. Limited geochemical data are available from the Clare River area in southern Mazinaw domain, but data from both Chappell (1978) and Bright (1986) indicate the presence of icelandites. Discrete targets cannot yet be defined, as metavolcanic rocks in the Clare River area have not been subdivided on the basis of chemistry. Little geochemistry exists on metavolcanic belts in the La France Lake or Clyde Forks areas in eastern Mazinaw domain. The best place to look for rocks of this suite is adjacent to syenogranitic intrusions. Detailed mapping and sampling will be necessary to distinguish the FIII rhyolite-icelandite suite from adjacent calc-alkalic metavolcanic rocks.

Porphyry Copper Mineralization

INTRODUCTION

Moore and Morton (1986) first suggested the presence of porphyry copper mineralization associated with plutonic rocks present in northern Mazinaw domain, specifically the Buffadison occurrence, but did not explore the concept in detail. The results from detailed mapping and assay samples collected in the Mazinaw–Marble Lake area in 1991 led Easton (1992a) to suggest that copper and gold occurrences in the western part of the synoptic area may be related to porphyry copper systems.

Figure 21 illustrates the distribution of known copper-gold mineralization in the Mazinaw–Marble Lake area, including new sites located during the course of mapping during the 1991 field season. All occurrences are hosted in marbles, generally dolomitic, and are associated with a series of medium-to coarse-grained, locally porphyritic, trondhjemitic stocks and dikes. The distribution of dolomite in this area does not appear to be stratigraphically controlled and, in fact, may represent a contact metamorphic effect related to this zone of dike and stock injection. Evidence of such alteration is evident along the Harlowe road, where calcitic marbles become progressively dolomitized adjacent to small porphyry dikes, with dolomitization crosscutting preserved bedding in the calcitic marbles.

Table 15. Chemical analyses of trondhjemite and dacite dikes from the Marble Lake area and tonalites and granodiorites of the Elzevir Suite.

	1	2	3	4	5	6	7	8	9
SiO_2	65.84	68.88	66.20	67.73	64.20	63.60	65.60	59.24	69.85
TiO_2	0.44	0.41	0.72	0.37	0.45	0.70	0.80	0.82	0.35
Al_2O_3	17.16	15.40	17.40	14.32	16.80	15.80	15.70	16.59	15.28
Fe_2O_3	2.99	2.54	0.45	1.00	0.40	1.90	2.30	NR	NR
FeO	1.84	1.56	1.05	3.17	3.30	3.48	2.80	7.17	2.45
MgO	1.28	1.39	1.25	1.43	3.10	2.33	1.60	3.52	1.21
MnO	0.04	0.03	0.03	0.09	0.05	0.11	0.10	0.13	0.04
CaO	2.84	3.35	3.41	3.59	2.40	4.96	3.80	6.12	2.37
Na_2O	4.58	4.52	4.21	4.84	4.70	4.03	4.90	4.43	4.62
K_2O	2.48	1.55	2.72	1.88	1.80	1.72	1.50	1.53	2.94
P_2O_5	0.16	0.16	0.15	0.20	0.13	0.09	0.20	0.20	0.09
CO_2	0.92	1.45	1.58	1.04	0.50	0.06	0.10	NR	NR
S	0.16	0.32	0.18	0.05	NR	NR	NR	NR	NR
LOI	1.83	1.79	NR	0.33	1.00	0.40	0.60	0.45	0.71
Total	99.63	101.33	100.23	100.04	98.83	100.0	100.0	100.0	100.0
Na/K ratio	1.8	2.8	1.6	2.6	2.6	2.3	3.3	2.9	1.6

1. 93RME-0012, tonalite, Helena stock, Corfu and Easton (1995) geochronology sample site, this study. 2. 91RME-0206, tonalite, Helena Mine, this study. 3. 80TRC-186, granitoid, Helena Mine, Malczak, Carter and Springer (1985). 4. #97, dacite dike, Moore and Morton (1986). 5. #81, dacite dike, Moore and Morton (1986). 6. average of 8 tonalites, Glamorgan Gneiss Complex, Easton (1987). 7. average tonalite, Glamorgan Gneiss Complex, Chesworth (1967). 8. average tonalite, Glamorgan and Weslemkoon intrusions, Lumbers et al. (1990). 9. average granodiorite, White Lake, Elzevir, Glamorgan and Weslemkoon intrusions, Lumbers et al. (1990).

Brecciation of the dolomite marbles has also been noted adjacent to the felsic dikes at some of the mineralized occurrences (e.g., Cook occurrence). Scapolite porphyroblasts hosted in muscovite schist layers occur within the marbles at the Cook occurrence. Scapolite is a common alteration product associated with carbonate-hosted porphyry systems in the Canadian Cordillera (G.E. Ray, geologist, British Columbia Geological Survey Branch, Victoria, British Columbia, personal communication, January 1992). Tetrahedrite is a common sulphide mineral at both the Helena and Cook occurrences. Engarite, a related copper-arsenic-sulphide is common in porphyry copper systems within the Canadian Cordillera (G.E. Ray, geologist, British Columbia Geological Survey Branch, Victoria, British Columbia, personal communication, January 1992) and, thus, the presence of tetrahedrite (which could be confused with engarite) in the area is to be expected.

Two samples of the Helena stock were analyzed as part of this study (analyses 1 and 2, Table 15). In addition, Malczak, Springer and Carter (1985) provided an analysis of the trondhjemite at the Helena Mine and Moore and Morton (1986) analyzed several dacite dikes that may be correlative with the suite (analyses 3 and 4, respectively, *see* Table 15). Table 15 also includes representative and average analyses from Elzevir Suite plutons for comparative purposes. The trondhjemite body at the Helena prospect is characterized by slightly higher Al_2O_3, S, CO_2 and K_2O, and lower CaO, contents in comparison to the Elzevir Suite tonalite plutons. The differences in S, CaO, CO_2 and K_2O contents could be related to the mineralization process. Al_2O_3 and K_2O are higher in the stock than in the felsic metavolcanic rocks of the Kashwakamak Formation. The major element chemistry of the stock is consistent with it representing an intrusion typical of a porphyry copper system. The age of the stock, 1267±5Ma (Corfu and Easton 1995), is just slightly younger than the age of the Kashwakamak Formation metavolcanic rocks, consistent with the geochemistry suggesting it is related to arc magmatism.

Table 16. Assay results from copper-gold prospects in the Mazinaw--Marble Lake area from this study as well as additional data *from* Papertzian (1984) and *from* Malczak, Carter and Springer (1985). All analyses by the Geoscience Laboratories, Ontario Geological Survey.

Sample Number	Easting (m)	Northing (m)	Au (ppb)	Cu (ppm)	Zn (ppm)	Other (ppm)	Comment
Helena Mine							
91RME-0205A	333540	4966900	<2	88	12		Tourmaline vein with sulphides intruded into calcite marble
91RME-0205B	333540	4966850	4	26000	148		Malachite-stained tremolite vein in dolomite
91RME-0206A	333561	4966850	4	153	42		Disseminated sulphide in trondhjemite
91RME-0206B	333601	4966850	4	112	103		Disseminated sulphide in trondhjemite
91RME-0207	333450	4966890	25	168	35		Disseminated sulphide in trondhjemite
HE-01	*see* Fig 21		<30	1150	ND	1 Sb	In dolomite
HE-02	*see* Fig 21		<30	275	ND	1 Sb	In dolomite
HE-03	*see* Fig 21		<30	4400	ND	22 Sb	Malachite-stained calcite marble
HE-04	*see* Fig 21		<30	265	ND	1 Sb	Gossan zone, quartz vein
HE-05	*see* Fig 21		<30	48	ND	2 Sb	Quartz vein
HE-06	*see* Fig 21		<30	84	ND	2 Sb	Quartz vein
80TRC-0182	NL		<30	795	ND	1 Sb	Vein in marble
80TRC-0187	NL		<30	184	ND	1 Sb	Vein in marble
80TRC-0188	NL		<30	192	ND	1 Sb	Vein in marble
Cook							
91RME-0118	332399	4966999	<2	8	34	1 Sb, 12 B	Calcite marble
91RME-0119	332460	4966990	<2	16	93	1 Sb, 136 B	Calcite marble
91RME-0120	332510	4966835	<2	7	115	1 Sb, 55 B	Aluminous calcite marble
91RME-0121	332424	4966300	<2	20	53	1 Sb, 21 B	Calcite-dolomite marble
91RME-0122	332424	4966270	<2	7	70	5 Sb, 251 B	Porphyry dike, disseminated pyrrhotite
91RME-0123	332338	4966172	<2	6	19	0.3 Sb, 5 B	Dolomite marble
91RME-0124	332280	4965861	11	210	<10		Malachite-stained dolomite
91RME-0126	332249	4965861	<2	9	13	1 Sb, 5 B	Dolomite marble
Buffadison							
91RME-0221	329882	4971645	50	7	14		Meta-arkose by pit, disseminated sulphide

Detection limit for Au is 2 ppb, <1 ppm for Sb, <5 ppm for B and Cu, <10 ppm for Zn. Background levels in area are generally close to detection limits. All 91RME-samples were analyzed for Pb and Ni, but no significant values were detected. ND = not determined; NL = no location given.

ASSAY RESULTS

Assay results obtained from sulphide-bearing feldspar-porphyry and trondhjemite dikes and adjacent marbles from the Marble Lake area collected during the course of mapping during the 1991 field season are listed in Table 16. The distribution of these samples is shown in Figures 19 and 21. Table 16 and Figure 23 also include previously reported assay results from Papertzian (1984) and Malczak, Carter and Springer (1985). Background levels of gold in the region are <10 ppb Au (Easton and Ford 1991).

Helena Mine

The Helena Mine operated in 1901, at which time 3 shafts were sunk (Malczak, Carter and Springer 1985). Figure 23, adapted from Malczak, Carter and Springer (1985) shows the geology of the Helena Mine and the location of workings. At least 10 small pits and trenches are present on the property, and 2 large quarry pits from an abandoned marble quarry are located about 75 m west of the shafts. An additional trench or shaft with a sizable dump, hosted in pyrite-, pyrrhotite- and chalcopyrite-bearing trondhjemite is located above the south face of the lowermost quarry (*see* Figure 23). This trench or shaft had not been shown by previous workers. Ore grades from this dump are unavailable.

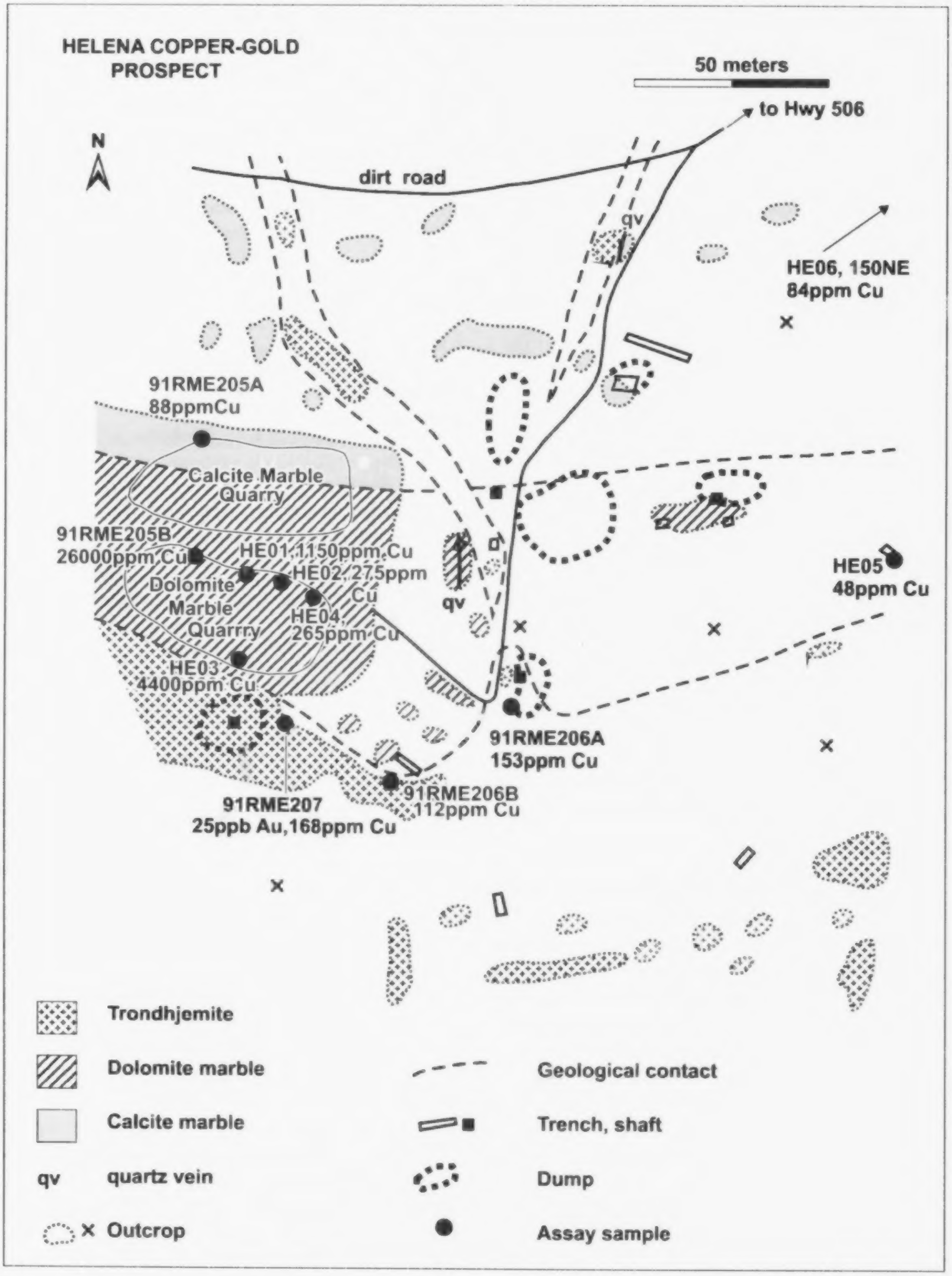

HELENA COPPER-GOLD PROSPECT
50 meters
to Hwy 506
N
dirt road
qv
HE06, 150NE
84ppm Cu
91RME205A
88ppmCu
Calcite Marble Quarry
91RME205B
26000ppm Cu
HE01 1150ppm Cu
HE02 275ppm Cu
Dolomite Marble Quarrry
HE04 265ppm Cu
HE03 4400ppm Cu
qv
HE05
48ppm Cu
91RME206A
153ppm Cu
91RME206B
112ppm Cu
91RME207
25ppb Au,168ppm Cu
Trondhjemite
Dolomite marble
Calcite marble
qv quartz vein
Outcrop
Geological contact
Trench, shaft
Dump
Assay sample

Figure 23. Sketch showing the Helena Mine site, location of assay samples, and copper, gold and antimony values. Geological data *from* R.M. Easton and T.R. Carter (respectively, unpublished data *from* 1980; and *in* Malczak, Carter and Springer 1985).

The most significant assay result comes from a sulphide-bearing, malachite-stained, tremolite vein that intruded dolomite marble and which yielded 2.6 weight % Cu (*see* Figure 23, sample 91RME-0205B). This is the highest value reported from the Helena Mine area, and may indicate that additional mineralization is yet to be discovered. Samples 91RME-0206A and 91RME-0206B were obtained from a trondhjemite body located on the prospect. These 2 samples were selected because of a low disseminated sulphide content for the purpose of geochemical characterization, yet they contain minor enrichments in gold and copper. Sample 91RME-0207 was collected from a sulphide-bearing trondhjemite outcrop located near the southwest shaft (*see* Figure 23), and contains anomalous values of gold and copper.

Papertzian (1984) reported assay samples from the Helena Mine site collected dominantly from marbles, as shown in Table 16 and Figure 23. Copper shows considerable variation, ranging from 48 to 4400 ppm. When included with the new assay results, it appears that there may be significant dispersed halo of copper mineralization within the vicinity of the Helena Mine. It is noteworthy that all the high assay values shown in Figure 23 cluster in the southeast corner of the prospect, near the trondhjemite–dolomite marble contact in the abandoned dolomite marble pit. Future exploration should concentrate on this part of the property, which is removed from most of the existing shafts and trenches. Most previous sampling has concentrated on quartz veins and carbonate rocks adjacent to these veins. Based on the data in Table 16, these may represent the least favourable prospects, with more favourable prospects being tremolite veins in the dolomite quarry and the trondhjemite body south of the quarry.

Cook Occurrence

Rocks adjacent to the Cook occurrence were recently well exposed due to road construction during 1991. Table 16 lists additional assay results from dolomitic marbles and a trondhjemite dike adjacent to this occurrence collected during the 1991 field season. Slightly anomalous values for gold and copper were obtained from these samples, which were originally collected to characterize the geochemistry of Grenville Supergroup marbles in the area. Consequently, samples with high disseminated sulphide contents were avoided. Nonetheless, even with this bias toward low sulphide samples, background levels for copper and gold are anomalous in some of these samples, particularly sample 91RME-0124.

CHARACTERISTICS OF PORPHYRY COPPER-GOLD AND COPPER-GOLD SKARN SYSTEMS IN THE CANADIAN CORDILLERA

Reviews of this type of deposit are presented by McMillan (1991) and McMillan and Panteleyev (1988). Porphyry deposits show a wide variation in characteristics, but some common features are listed below and in Table 17:

- mineralization is widely dispersed in porphyritic intrusions or adjacent country rocks
- most are related to calc-alkalic to alkalic, epizonal, porphyritic intrusions (typical depths of emplacement 2 to 4 km)
- typical host rock suites are granodiorite-granite or diorite-syenite
- dike swarms and breccia pipes typically accompany mineralization
- both the intrusions and the country rock are strongly and pervasively fractured; alteration is widespread and zoned

Alteration associated with the 2 main geochemical classes of deposits differ. Calc-alkalic deposits have central potassic alteration zones, defined by secondary biotite or metasomatic potassium feldspar, passing outward through successive envelopes of phyllic alteration (sericite and quartz), then propylitic

Table 17. Comparison of porphyry copper deposit features with copper-gold occurrences found in Mazinaw domain.

Cordillera	**Mazinaw domain**
- Mineralization is widely dispersed in porphyritic intrusions or adjacent country rocks.	- Mineralization is widely dispersed in country rocks and is present in intrusive rocks.
- Grades are generally low, mining is by large tonnage methods.	- No data.
- Most are related to calc-alkalic to alkalic, epizonal, porphyritic intrusions (typical depths of emplacement 2 to 4 km).	- Mazinaw domain mineralization appears to be related to epizonal intrusions of calc-alkalic to weakly alkalic affinity near volcanic centres.
- Typical host rock suites are granodiorite-granite or diorite-syenite.	- Trondhjemites may represent altered granodiorites. Buffadison occurrence associated with diorite.
- Multiple intrusions are characteristic, but mineralization relates to specific intrusive episodes.	- Mineralization appears to be related to one plutonic suite, which was intruded late in development of supracrustal sequence.
- Dike swarms and breccia pipes typically accompany mineralization.	- Brecciation reported from Cook occurrence, locally present at Helena prospect.
- Both the intrusions and the country rock are strongly and pervasively fractured.	- Buffadison occurrence.
- Alteration is widespread and zoned.	- Difficult to ascertain as M_2 metamorphism has overprinted alteration zones, although dolomitization adjacent to plutons may result from alteration. M_2 biotite porphyroblasts are generally red in mineralized areas and green elsewhere. This may reflect an earlier alteration signature. Feldspars in trondhjemites are not fresh, and could represent albitic alteration from original granodiorite composition. Moore and Morton (1986) report alteration adjacent to Buffadison occurrence and stocks north of Harlowe, but features of alteration were not characterized. More work needs to be done in Mazinaw domain on this topic, however preliminary data suggest widespread alteration around the intrusions may be present.
- Size is important. A deposit in the Cordillera must contain at least 20 million tonnes of at least 0.1% Cu to be classed as a porphyry copper deposit.	- No data.

alteration (epidote, chlorite and albite), into unaltered rock. In contrast, alkalic deposits have central potassic or albitic plagioclase alteration zones, and flanking, more extensive propylitic envelopes. Generally, alteration is patchier, and no phyllic zone is developed (McMillan 1991). In the idealized model (Figure 24), the alteration is portrayed as a series of shells around the intrusion. Hydrothermal systems are dynamic, however, and, as they cool, the hydrothermal systems can "collapse" downward and younger alteration can overprint and destroy younger alteration (McMillan 1991).

Typical sulphides are pyrite, bornite, chalcopyrite and molybdenite, hypogene chalcocite occurs locally (McMillan 1991). Alkalic deposits lack economic concentrations of molybdenite, and commonly have associated pyrrhotite (McMillan 1991). Metal zoning characterizes porphyry deposits. The central, copper-enriched zones are enclosed in pyritic envelopes. In alkalic deposits, core zones typically carry chalcopyrite, bornite, magnetite and pyrrhotite with gold (McMillan 1991).

Figure 24 shows the possible inter-relationship of sediment-hosted gold, skarn, epithermal vein and porphyry deposits. As noted by McMillan (1991), there is a transition between porphyry copper-gold and epithermal gold systems. Jones, Leveille and Thompson (1991) describe a composite zoning model for a gold-enriched porphyry copper deposit. Central barren zones give way to zones characterized by: molybdenum; bornite-gold; chalcopyrite; pyrite with gold in shear zones; lead-zinc-silver; gold-silver veins; and finally, epithermal gold. They also note multiple gold targets within these systems, particularly if they are hosted in carbonate-rich stratigraphic sequences.

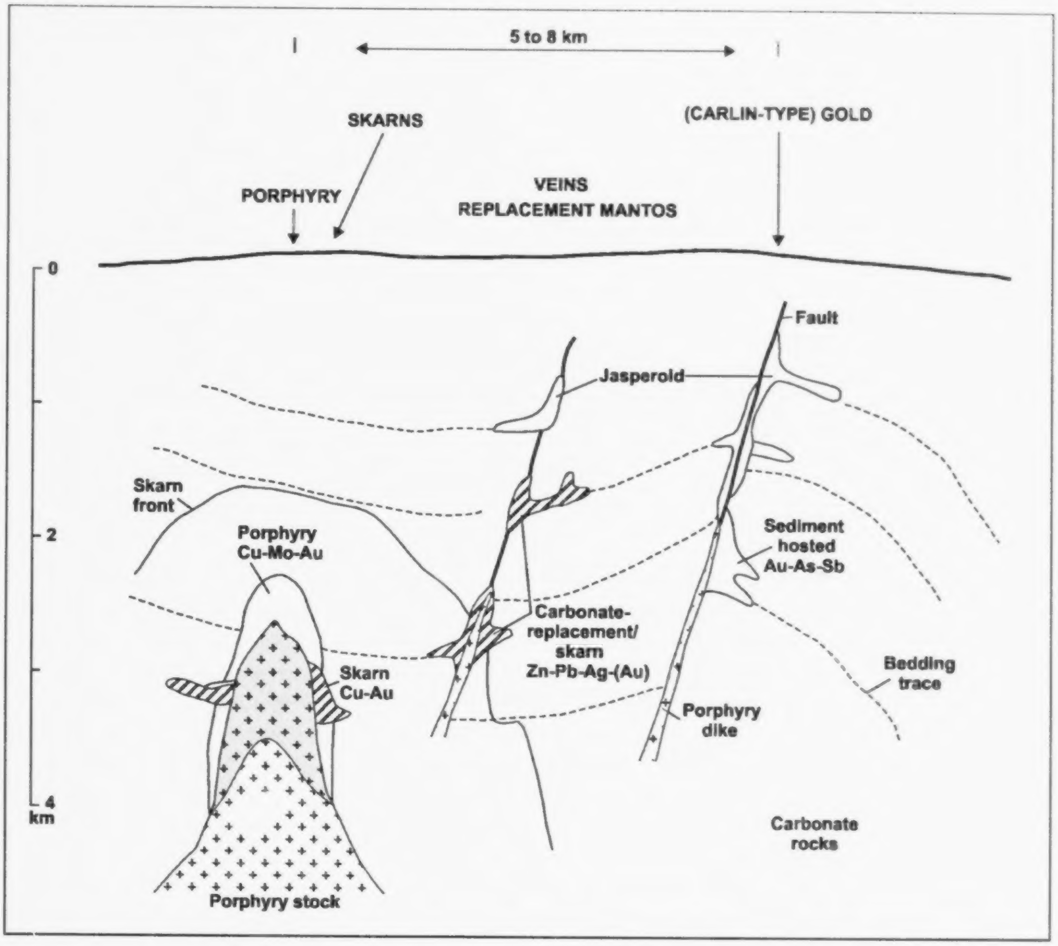

5 to 8 km
SKARNS
(CARLIN-TYPE) GOLD
PORPHYRY
VEINS
REPLACEMENT MANTOS
0
2
4
km
Fault
Jasperoid
Skarn front
Porphyry Cu-Mo-Au
Sediment hosted Au-As-Sb
Carbonate-replacement/ skarn Zn-Pb-Ag-(Au)
Skarn Cu-Au
Bedding trace
Porphyry dike
Carbonate rocks
Porphyry stock

Figure 24. Schematic model showing links between porphyry districts and sediment-hosted gold deposits in the Canadian Cordillera (*modified from* McMillan 1991).

A PORPHYRY COPPER-GOLD MODEL FOR MAZINAW DOMAIN

Table 17 compares the features of porphyry copper deposits with the copper-gold mineralization present within the Mazinaw domain. Copper-gold mineralization within the Mazinaw area matches many of the features present in porphyry copper systems in the Cordillera. Based on these similarities, Figure 25 was constructed to illustrate the relation of the surface mineralization in the Mazinaw area to a hypothetical porphyry copper system. Key features to note are that the surface exposures near Michell Bay probably occur in the transition zone between a porphyry copper system and an epithermal vein system or copper-gold-skarn system. The localized, high-grade, vein-related mineralization at the Helena and Cook occurrences represent this vein/skarn-type of mineralization. The main porphyry system likely occurs at depth, probably somewhere beneath the area centred on Michell Bay between the Cook occurrence and the Helena prospect. Also illustrated in Figure 25 are possible relations between the porphyry copper and other mineral prospects in the area, following the model of Jones, Leveille and Thompson (1991). It is most likely that a calc-alkalic system is represented in the Mazinaw domain. The lack of molybdenum, the common occurrence of gold, the mineral assemblage at the Buffadison occurrence, and the limited geochemistry suggests that we may be seeing a weakly alkalic porphyry system that is of the volcanic-hosted to classic porphyry type (McMillan 1991).

To date, this type of mineralization is known only to be present in northwestern Mazinaw domain. If the conditions for mineralization require a spatial association with volcanic rocks, only 2 other potential target areas exist in the Mazinaw domain. First, a major accumulation of volcanic rocks is present in the Clyde Forks to Flower Station area, which locally contains regional geochemical anomalies of copper (Easton 1988). However, porphyritic plutonic rocks have not yet been documented from that area. Second, a diverse suite of volcanic rocks occurs in the Clare River area in southern Mazinaw domain, but porphyritic plutonic rocks have not been documented there. Based on existing regional geologic information, the Marble Lake area is the best target area for this type of mineralization within the Mazinaw domain.

Elsewhere in the Central Metasedimentary Belt, no other examples of this type of mineralization are known. The paucity of calc-alkalic volcanic and plutonic rocks elsewhere in the Central Metasedimentary Belt (Easton 1992b) suggests that such mineralization may be limited to the Mazinaw domain.

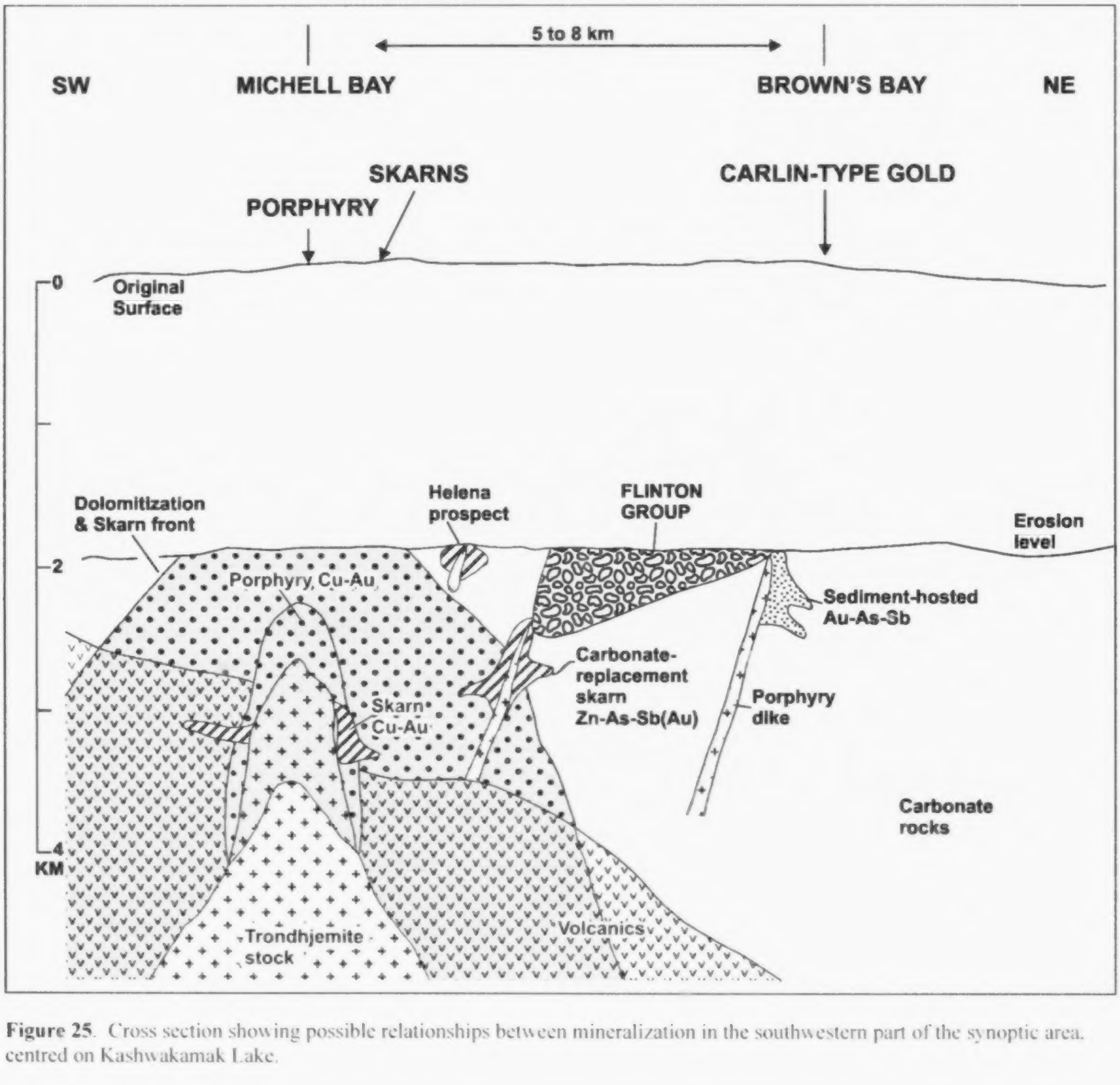

5 to 8 km
SW
MICHELL BAY
BROWN'S BAY
NE
SKARNS
PORPHYRY
CARLIN-TYPE GOLD
0
Original Surface
2
4
KM
Dolomitization & Skarn front
Helena prospect
FLINTON GROUP
Erosion level
Porphyry Cu-Au
Sediment-hosted Au-As-Sb
Carbonate-replacement skarn Zn-As-Sb(Au)
Porphyry dike
Skarn Cu-Au
Carbonate rocks
Trondhjemite stock
Volcanics

Figure 25. Cross section showing possible relationships between mineralization in the southwestern part of the synoptic area, centred on Kashwakamak Lake.

GUIDELINES FOR COPPER-GOLD EXPLORATION

The porphyry copper model provides prospectors with a conceptual framework for explaining the occurrence of widespread, generally low-grade copper-gold mineralization within northwestern Mazinaw domain. Exploration should concentrate on the Michell Bay area, and the Buffadison occurrence, and should focus on the late trondhjemite intrusive rocks and the marbles adjacent to them. If a porphyry copper system is present, it is likely that surface exposures are located in the outer shell of the mineralized zone, and that more significant mineralization lies at depth. In the Cordillera, induced polarization has been a successful tool in outlining the pyritic shell of porphyry copper systems, and such methods may be applicable here. Despite the effects of the M_2 metamorphic event, detailed mineralogic work in the vicinity of the copper-gold deposits may be able to outline the alteration signature of the intrusive rocks. Knowledge of the detailed alteration pattern will also assist in exploration. M_2 metamorphism has caused recrystallization of ore and gangue minerals in the rocks, but, in the case of sulphides, it appears to have increased grain size without causing any substantive remobilization.

Sulphide Mineralization in Carbonate Rocks

Some 130 marble analyses are available from the synoptic area when the databases of Grant, Papertzian and Kingston (1989) and this study are combined. This marble database not only provides a baseline for determining background levels for carbonate rocks within the study area, but also allows for determination of anomalous samples within the synoptic area (Figure 26). This is illustrated in Figure 27, which plots Pb + Zn or Cu + Ni versus CaO content of the marbles. CaO content is used as an abscissa simply because it provides and indication of the dolomite and calc-silicate versus calcite content of the marbles, and Pb + Zn and Cu + Ni are grouped together because of probable depositional associations with dolomitic and calcitic marbles, respectively. Assay samples from marbles collected during this study are also shown in Figure 27, plotted at CaO = 0.

Only a few anomalous samples are present (*see* Figure 27) and, of these, only 2 samples are anomalous with respect to both Cu + Ni and Pb + Zn, namely sample 528C from the site of the Helena Au-Cu Mine, and sample 593, from a locality on Frontenac County road 506, 1 km west-northwest of the Clarendon–Miller Township office (UTM 345850E 4977950N). Two other slightly anomalous samples on the Cu + Ni plot (*see* Figure 27, unnumbered boxes above 50 ppm reference line) are from a carbonate-amphibolite unit (unit 3, Ardoch area: Pauk 1987), and the slightly higher Cu + Ni contents probably reflect the impure nature of these carbonates. Similarly, samples from the Mair Lake belt, Palmerston Lake area, are slightly anomalous in Pb + Zn (*see* Figure 27), most likely due to the high non-carbonate content of these rocks.

Samples PM142 and 666 are in the same carbonate belt as sample 593 (Figure 28), and may indicate a zone of mineralization north of Swamp Creek between the North road and Frontenac County road 506. Pauk (1987) shows a pyrite occurrence near sample 593, and reports assay values of 40 ppb Au and 157 ppm Cu from this site (LBP-5194: Pauk 1987, p.42). The James Mine (Smith 1958; Pauk 1987) is located on strike 3 km northeast of sample 593 and Frontenac County road 506 (*see* Figure 28), and mineralization has been traced 1 to 2 km further north to Little Green Lake (Pauk 1987). Thus, the belt of marbles showing consistently above average Pb + Zn values, and locally above average Cu values has a possible strike length of almost 8 km (*see* Figure 28). In addition, multi-element lake sediment geochemical anomalies are reported from James Lake, near the site of the James Mine, and from Little Green Lake (Ontario Geological Survey–Geological Survey of Canada 1977a), specifically Cu, Zn, As, Hg and Mo. Sampling density of this regional lake sediment survey (Ontario Geological Survey–Geological Survey of Canada 1997a) was such that no other sites in the Swamp Creek marble belt were included, although it is worth noting that these 2 sites were the strongest anomalies in the synoptic area.

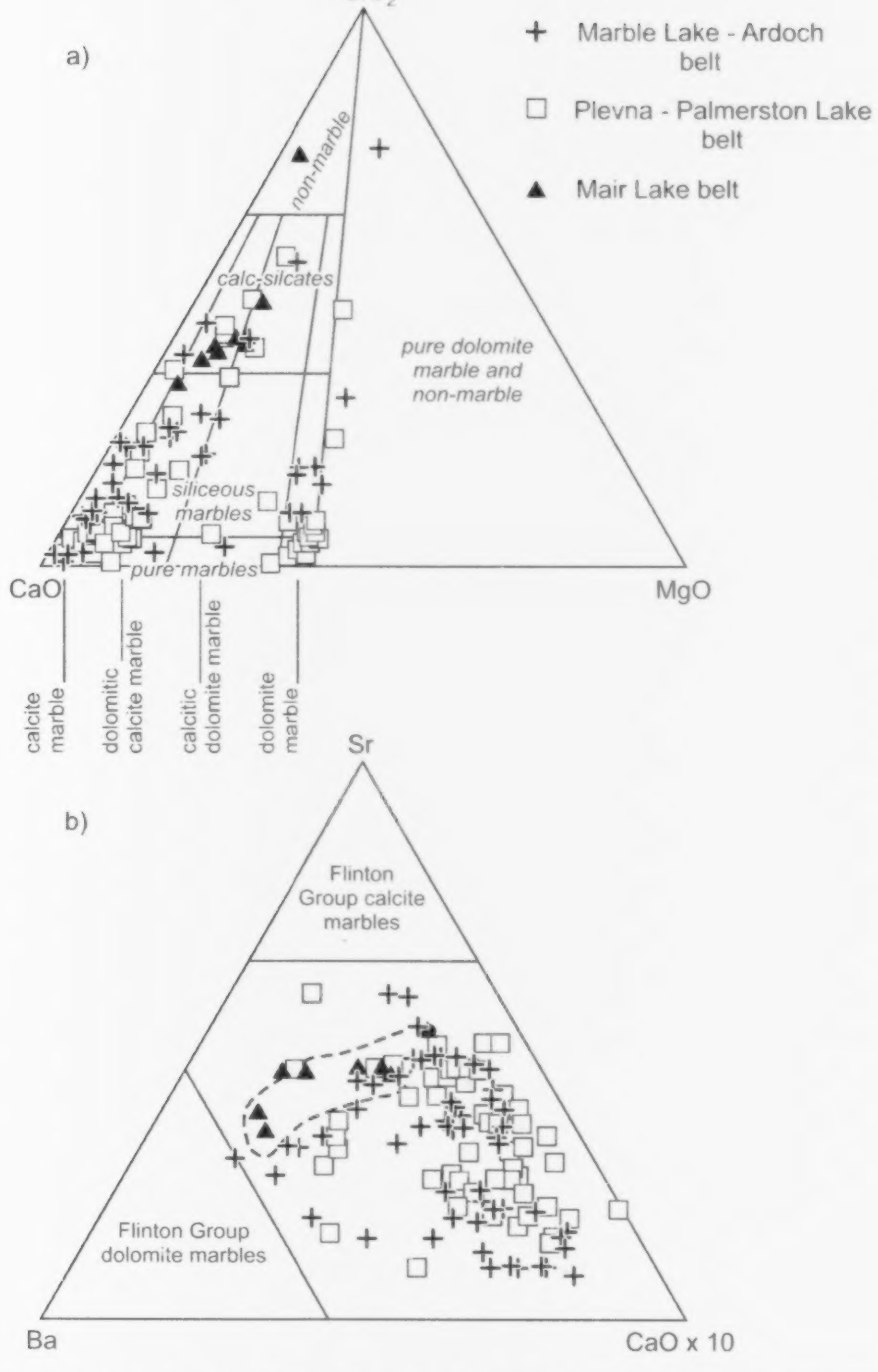


Figure 26. Chemistry of marbles from the synoptic area. a) CaO–SiO_2–MgO diagram shows the amount of silicate impurities in the marbles. Note high silica contents of marbles from the Mair Lake belt. b) Ba–Sr–(CaO*10) diagram shows the compositional range of Grenville Supergroup marbles from the synoptic area. Dashed line shows compositional field for Mair Lake belt marbles. Data *from* this study and *from* Grant, Papertzian and Kingston (1989).

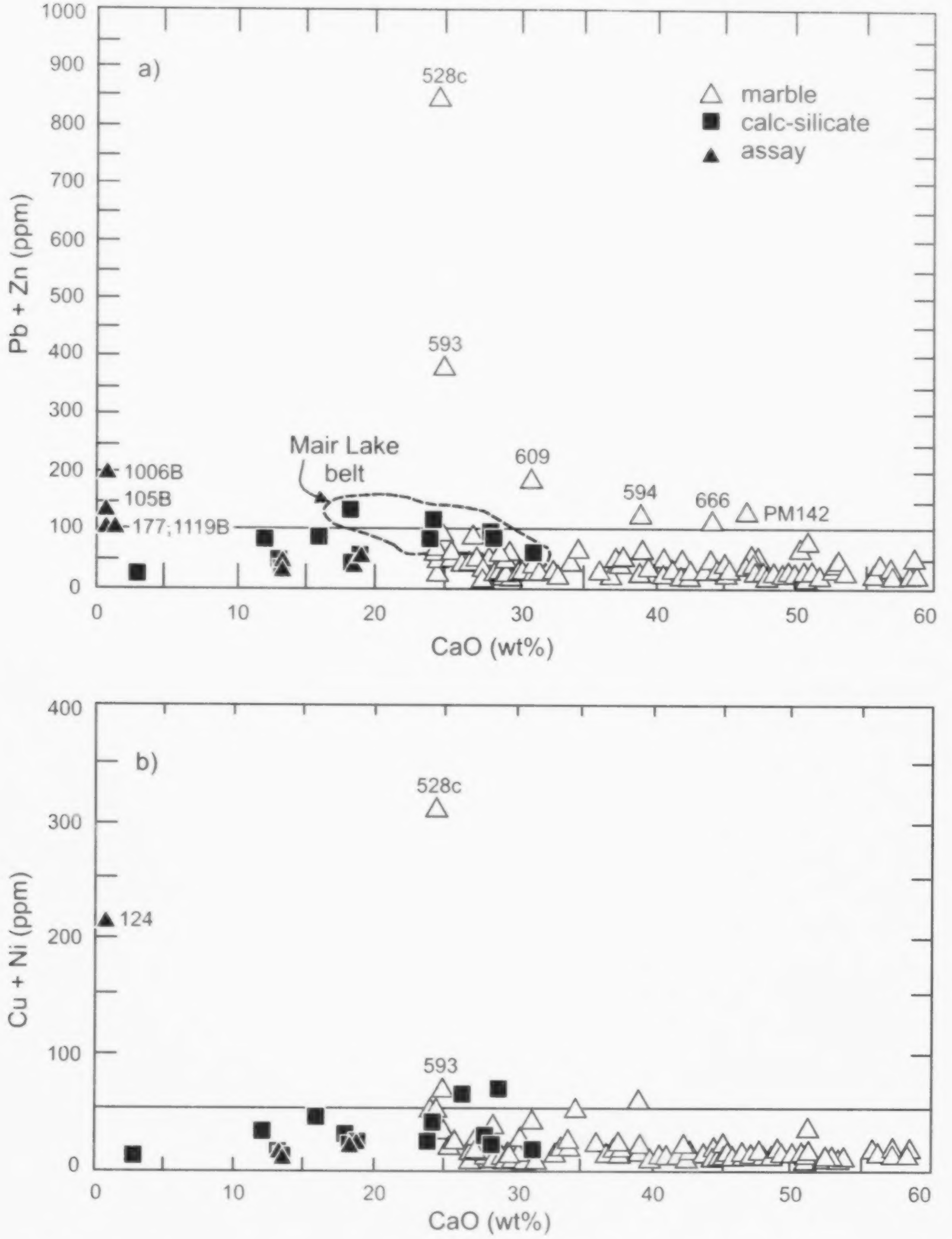


Figure 27. Chemistry of marbles from the synoptic area. a) Pb + Zn versus CaO diagram. b) Cu + Ni versus CaO diagram. See text for discussion. Data *from* this study, Pauk (1987) and Grant, Papertzian and Kingston (1989).

Furthermore, as discussed under "Geophysics", a point-source magnetic high occurs near Swamp Lake at the west end of the Swamp Creek marble belt, and a lenticular magnetic high occurs between the North road and Frontenac County road 506 in the vicinity of samples P5194-593 and PM142. As the Swamp Creek marble belt is the only area within the synoptic area with several anomalous values, and associated aeromagnetic anomalies, further exploration is warranted. Sampling should focus on the dolomitic marbles, because the highest values reported to date are from dolomitic marbles near the James Mine (sample 593).

The Swamp Creek marble belt is bounded, to the south, by the Fernleigh belt of Flinton Group strata and, to the north, by Bishop Corners Formation pelites in the vicinity of Green Lake and Bishop Corners Formation metaconglomerates and metapelites south of Sand Lake (*see* Figure 28). This proximity might not be fortuitous, as the dolomitization and related quartz veining present in the mineralized carbonate belt might be related to proximity to the Flinton Group basal unconformity, with the unconformity horizon serving to focus fluid flow. In addition, a paragneiss belt is also present adjacent the southern margin of the Swamp Creek Belt (*see* Figure 28). As discussed previously, this horizon is extremely deformed, with some of the paragneisses having a mylonitic character. These paragneisses are more deformed than the adjacent marbles, and it is possible they may be in thrust contact with the marbles. If this is the case, then the thrust contact (now cryptic) may also have been important in focussing mineralizing fluids.

Sample 609 (*see* Figure 27) is from the Mosque Lake road, Palmerston Lake area. Because it is only a single, moderately mineralized sample, its significance is difficult to ascertain. Sample 594 is from Plevna, close to the location of assay sample 177, which was collected from a construction pit in a schoolyard (*see* Figure 27). Although not strongly mineralized, these samples may indicate yet undiscovered mineralization in the area. Assay sample 105B (*see* Figure 27) is from a Flinton Group dolomitic marble just north of the Frontenac County road 506–Ardoch road junction, and was the only anomalous Flinton Group sample assayed in this study.

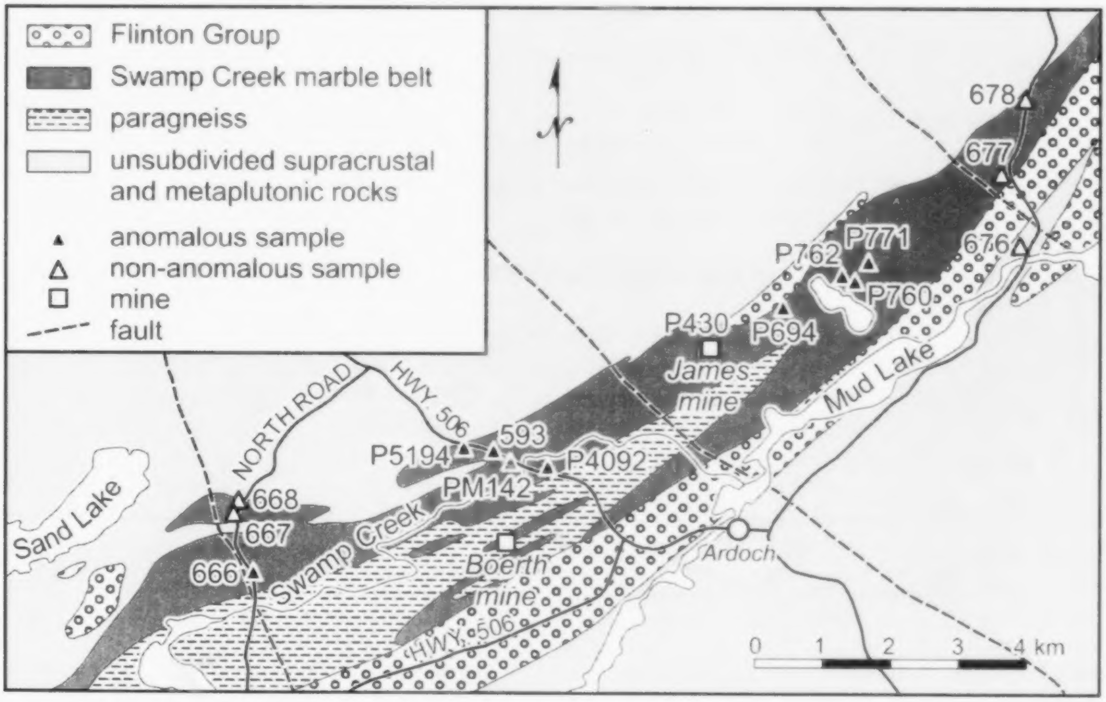

Flinton Group
Swamp Creek marble belt
paragneiss
unsubdivided supracrustal and metaplutonic rocks
anomalous sample
non-anomalous sample
mine
fault
N
678
677
676
P771
P762
P760
P430
P694
James mine
Mud Lake
HWY. 506
NORTH ROAD
593
P5194
P4092
PM142
668
667
666
Sand Lake
Swamp Creek
Boerth mine
Ardoch
HWY. 506
0 1 2 3 4 km

Figure 28. Geological sketch map showing location of assay samples in the Ardoch area, in the vicinity of the Boerth and James mines. Data from this study, Pauk (1986) and Grant, Papertzian and Kingston (1989).

Sulphide Mineralization in the Flinton Group

Assays from stratiform pyrite layers within Myer Cave Formation graphitic schists show little enrichment in gold, copper, nickel or lead, suggesting few other metals are associated with pyrite in these schists (*see* Appendix 2). Similar pyritic schists in the Sulphide–Hungerford area in the Clare River area were mined for pyrite in the early 1900s. However, crosscutting sulphide veins in the Myer Cave Formation show considerable enrichment in Zn and minor Pb enrichment (analyses 91RME-1012A and 91RME-1012B, *see* Appendix 2).

Other Examples

Both Smith (1958) and Pauk (1983) report the presence of stratiform layers and lenses of massive pyrite and pyrrhotite up to 70 cm thick and at least 2 m long occurring intermittently over a strike length of 1.5 km, northeast of Sunday Lake. The sulphide mineralization forms gossans near the contact between hornblende-biotite schists (volcanic-derived metawackes?) and siliceous metasedimentary rocks (metawackes to meta-arenite). Sample 92RME-1054 (*see* Appendix 2) from one of the gossan zones near rusty-weathering, Paleozoic conglomerate may have been concentrated during pre-Paleozoic weathering (cf. Di Prisco and Springer 1991).

Pauk (1983) describes a second mineralized zone, 13 m wide and 500 m long, hosted in a fine-grained granite north of Sunday Lake. Mineralization consists of quartz veins containing stringers of galena, sphalerite, chalcopyrite and pyrite. Sample 92RME-1056 (*see* Appendix 2) is a grab sample from one of these veins.

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Appendix 1

Listing of Geochemical Data on Rock Units in the Study Area Collected as Part of This Study

Notes:

Universal Transverse Mercator (UTM) co-ordinates are provided in North American Datum 1927 (NAD27), Zone 18.

NA = not analyzed
NC = not calculated
NR = not reported
< = less than symbol indicates element was below the detection limit in the sample
> = greater than symbol indicates element was above instrument calibration limit

Appendix 1. Listing of geochemical data on rock units in the study area collected as part of this study

Sample Name	Easting (m)	Northing (m)	Township	Rock Type	Formation or Pluton	SiO_2 (wt %)	TiO_2 (wt %)	Al_2O_3 (wt %)
90RME-0206	316949	4965037	Anglesea	anorthositic gabbro	Killer Creek suite	51.96	1.77	21.79
91RME-0002	340844	4977650	Clarendon	litharenite	Mississagagon	0.73	0.03	0.39
91RME-0021	326500	4971400	Barrie	icelandite/wacke	Mazinaw Lake	63.69	1.33	13.60
91RME-0050	338830	4979140	Clarendon	litharenite	Mississagagon	66.12	0.62	15.40
91RME-0091	347854	4967477	Clarendon	mudstone	Fernleigh	52.83	0.65	11.29
91RME-0092	343222	4974504	Clarendon	schist	Fernleigh	60.34	1.31	19.00
91RME-0093	343188	4974460	Clarendon	schist	Fernleigh	65.76	1.48	16.04
91RME-0094	342250	4974250	Clarendon	semi-pelite	Mississagagon	56.88	0.88	16.94
91RME-0095	341812	4973499	Clarendon	sulphide schist	Myer Cave	52.56	0.71	11.73
91RME-0100	338175	4971075	Barrie	calcite marble	Myer Cave	2.09	0.03	0.35
91RME-0106	344126	4974625	Clarendon	calcite marble	Myer Cave	3.17	0.05	0.45
91RME-0107	341664	4973144	Clarendon	schist	Fernleigh	43.61	0.79	12.92
91RME-0108	334979	4966891	Barrie	sulphide schist, unlaminated	Myer Cave	51.67	0.78	12.17
91RME-0109	342119	4973657	Clarendon	sulphide schist, laminated	Myer Cave	52.71	0.69	11.33
91RME-0110	344900	4974735	Clarendon	schist	Fernleigh	49.91	0.65	11.25
91RME-0113	332392	4967365	Barrie	sulphide schist, unlaminated	Myer Cave	27.98	0.35	5.55
91RME-0114	332392	4967365	Barrie	sulphide schist, laminated	Myer Cave	11.26	0.21	3.31
91RME-0118	332399	4966999	Barrie	calcite marble	Mississagagon	4.71	0.06	1.52
91RME-0120	332510	4966835	Barrie	calcite marble	Mississagagon	20.99	0.28	4.83
91RME-0126	332249	4956861	Barrie	dolomite marble	Mississagagon	3.78	0.02	0.11
91RME-0133	357109	4985658	South Canonto	biotite-garnet-sillimanite schist	Myer Cave	59.62	1.19	18.39
91RME-0134	356939	4985596	South Canonto	calcite marble	Myer Cave	2.43	0.03	0.29
91RME-0135	345202	4974868	Clarendon	schist	Fernleigh	48.37	0.61	10.34
91RME-0136	344512	4974657	Clarendon	schist	Fernleigh	49.89	0.52	9.54
91RME-1030	339275	4977100	Clarendon	calcite marble	Mississagagon	1.27	0.02	0.32
91RME-1039	338900	4976800	Barrie	felsite	Mazinaw Lake	63.90	0.33	13.16
91RME-1040	338600	4976050	Barrie	gabbro	Killer Creek suite	50.84	1.28	16.89
91RME-0175	340481	4975930	Clarendon	litharenite, intercalated with granite cobble conglomerate	Norway Lake	66.55	1.26	13.63
91RME-0181	338300	4975600	Clarendon	granite, weathered beneath conglomerate	Ore Chimney	72.60	0.28	13.18
91RME-0182	339200	4975500	Clarendon	wacke, late hornblende phenocrysts	Norway Lake	52.24	1.66	17.99
91RME-1114	333210	4973990	Barrie	felsite	Mazinaw Lake	76.74	0.18	10.98
91RME-1115	332990	4973985	Barrie	granite	Abinger	68.76	0.68	14.17
91RME-1116	330800	4973220	Barrie	leucogabbro	Killer Creek suite	50.37	1.17	17.48
91RME-0014	335450	4983430	Abinger	granite	Abinger	72.42	0.27	14.46
91RME-0110	344900	4974735	Clarendon	pelite	Fernleigh	50.10	0.64	11.43
91RME-0188B	330090	4965385	Barrie	pelite	Ore Chimney	50.19	1.14	20.35
91RME-0188C	330090	4965385	Barrie	pelite	Ore Chimney	63.04	1.00	15.63
91RME-0188E	330090	4965385	Barrie	pelite	Ore Chimney	62.49	0.80	13.47
91RME-0190	336950	4974580	Barrie	granite, cobble in conglomerate	Norway Lake	76.14	0.26	12.81
91RME-0206	333561	4966850	Barrie	tonalite, copper-bearing	Helena stock	68.88	0.41	15.40
91RME-0232	340660	4973225	Clarendon	garnet-biotite pelite	Bishop Corners?	59.81	1.23	19.71
91RME-0234	339020	4975880	Clarendon	granite	Norway Lake	72.16	0.28	13.31
91RME-1016	339570	4972370	Barrie	felsite	Mazinaw Lake	68.39	0.46	16.58
91RME-1023	332200	4972980	Barrie	felsite	Mazinaw Lake	68.20	0.67	13.69
91RME-1068	340890	4975870	Clarendon	tourmaline schist		47.53	0.95	17.34

Appendix 1. continued

Sample Name	Fe_2O_3 (wt %)	FeO (wt %)	MnO (wt %)	MgO (wt %)	CaO (wt %)	Na_2O (wt %)	K_2O (wt %)	P_2O_5 (wt %)	LOI (wt %)	S (wt %)	H_2O+ (wt %)	CO_2 (wt %)
90RME-0206	1.82	3.72	0.07	2.4	8.61	4.51	0.85	0.32	0.77	<0.01	0.74	0.21
91RME-0002	0.26	0.61	0.04	20.37	30.18	0.07	0.11	0.03	47.02	<0.01	0.08	54.75
91RME-0021	2.96	5.76	0.20	1.45	3.10	4.63	2.13	0.46	0.64	0.03	0.66	0.22
91RME-0050	1.10	2.91	0.03	3.37	2.46	3.84	3.09	0.13	0.90	0.01	0.72	0.10
91RME-0091	1.17	4.37	0.07	6.67	8.76	1.84	3.75	0.15	7.77	0.21	1.07	6.46
91RME-0092	5.73	6.09	0.48	3.10	1.08	0.74	1.67	0.23	0.51	0.01	0.87	0.03
91RME-0093	9.89	1.40	0.03	0.44	0.33	1.99	1.82	0.10	1.41	0.01	1.14	0.04
91RME-0094	9.17	0.95	0.09	2.68	2.33	2.29	6.81	0.18	1.02	<0.01	0.68	0.03
91RME-0095	2.00	4.06	0.09	3.68	8.89	1.80	3.07	0.26	9.83	<0.01	0.78	11.62
91RME-0100	0.10	0.20	0.01	0.61	53.22	0.12	0.18	0.02	42.27	0.10	0.10	48.57
91RME-0106	0.17	0.20	0.01	0.48	52.39	0.12	0.23	0.02	42.03	0.02	0.12	47.36
91RME-0107	1.12	4.64	0.11	8.54	10.27	1.47	3.94	0.18	11.73	0.63	1.13	10.43
91RME-0108	3.20	2.50	0.05	4.21	8.54	1.25	3.67	0.17	10.38	<0.01	1.46	8.19
91RME-0109	6.49	2.44	0.15	3.36	6.73	1.58	2.93	0.25	10.14	<0.01	0.51	11.95
91RME-0110	1.33	4.69	0.08	7.10	9.67	1.80	3.61	0.14	8.45	0.14	1.23	7.43
91RME-0113	0.62	2.36	0.09	6.98	25.92	0.45	1.87	0.14	24.65	<0.01	0.70	31.11
91RME-0114	0.63	0.74	0.03	1.49	44.02	0.26	1.16	0.06	35.29	0.67	0.34	40.80
91RME-0118	0.69	0.02	0.02	2.15	49.11	0.07	0.40	0.04	41.18	0.07	0.23	45.90
91RME-0120	0.39	1.90	0.04	2.75	35.64	0.94	0.76	0.11	30.59	<0.01	0.49	34.70
91RME-0126	0.28	0.25	0.03	20.56	29.46	0.01	0.09	0.04	45.36	<0.01	0.05	51.50
91RME-0133	2.39	10.98	0.03	1.44	0.36	0.65	3.11	0.15	1.13	0.01	1.58	0.08
91RME-0134	0.12	0.20	0.01	0.42	53.34	0.23	0.17	0.02	42.58	0.07	0.12	50.51
91RME-0135	1.39	3.65	0.09	6.79	10.42	1.88	3.24	0.14	12.56	<0.01	1.01	11.02
91RME-0136	0.91	3.39	0.11	5.72	13.81	1.79	2.45	0.12	11.14	0.05	1.08	9.87
91RME-1030	0.22	0.45	0.05	20.58	30.20	0.04	0.10	0.04	46.37	<0.01	0.08	52.70
91RME-1039	0.77	2.18	0.12	3.51	4.53	2.97	2.38	0.10	5.33	0.23	1.36	3.48
91RME-1040	3.68	6.95	0.17	5.00	7.03	3.81	2.10	0.35	1.99	0.01	1.15	0.67
91RME-0175	6.75	1.17	0.07	1.61	0.99	2.64	3.15	0.23	1.60	<0.01	1.53	<0.03
91RME-0181	2.08	0.51	0.04	0.26	0.71	3.85	4.89	0.03	0.70	<0.01	0.85	0.05
91RME-0182	3.25	7.15	0.16	3.03	6.72	4.52	1.67	0.41	0.50	<0.01	0.94	<0.03
91RME-1114	2.76	1.12	0.07	0.49	1.77	3.28	1.35	0.01	0.80	<0.01	0.58	0.08
91RME-1115	2.10	2.00	0.09	0.72	1.88	4.77	2.84	0.16	1.10	0.01	0.58	0.37
91RME-1116	2.69	4.57	0.13	6.29	10.96	2.64	0.94	0.23	1.20	0.05	1.39	0.09
91RME-0014	0.59	1.38	0.03	0.76	1.16	5.09	2.00	0.16	0.78	0.18	NA	0.41
91RME-0110	1.03	4.48	0.08	6.70	9.42	1.64	3.66	0.15	8.33	0.09	NA	7.28
91RME-0188B	3.29	8.02	0.15	5.14	2.19	1.30	4.43	0.28	1.28	<0.03	NA	<0.30
91RME-0188C	2.20	5.70	0.09	3.69	1.55	1.46	2.64	0.36	0.74	<0.03	NA	<0.30
91RME-0188E	1.97	5.92	0.24	4.08	4.12	0.44	2.68	0.19	0.97	<0.03	NA	<0.30
91RME-0190	3.09	<0.20	0.01	0.12	0.19	3.90	4.14	0.05	0.00	<0.03	NA	<0.30
91RME-0206	0.81	1.56	0.03	1.39	3.35	4.52	1.55	0.16	1.79	0.32	NA	1.45
91RME-0232	4.91	4.44	0.15	2.68	0.30	0.26	3.17	0.18	1.02	<0.03	NA	<0.30
91RME-0234	2.26	0.74	0.03	0.43	0.84	4.03	4.54	0.05	1.17	0.03	NA	0.61
91RME-1016	0.88	2.02	0.03	1.55	1.45	5.67	2.50	0.22	0.44	<0.03	NA	<0.30
91RME-1023	4.32	2.92	0.68	0.75	1.53	4.29	1.38	0.12	1.10	<0.03	NA	0.81
91RME-1068	5.57	2.15	0.13	4.19	16.99	1.49	1.93	0.32	0.72	<0.03	NA	<0.30

Appendix 1. continued.

Sample Name	FeO (wt %)	Total (wt %)	Mg Number	CIA	Cr (ppm)	Ni (ppm)	Co (ppm)	Cu (ppm)	Sc (ppm)	V (ppm)	Zn (ppm)	Pb (ppm)	Mo (ppm)
90RME-0206	5.36	98.59	44.40	60.93	42	29	15	114	11	216	51	11	<8
91RME-0002	0.84	99.84	97.73	1.27	<10	8	5	6	2	9	8	<10	<10
91RME-0021	8.43	99.98	23.47	58.52	<10	5	11	25	17	51	82	<10	<10
91RME-0050	3.90	99.98	60.63	62.37	56	20	8	<5	9	53	50	<10	<10
91RME-0091	5.42	99.53	68.67	58.86	50	34	14	46	12	71	128	17	<10
91RME-0092	11.25	100.29	32.94	84.59	58	49	21	19	24	102	34	12	<10
91RME-0093	10.30	100.70	7.07	79.64	61	18	10	<5	17	137	10	<10	<10
91RME-0094	9.21	100.22	34.17	59.77	41	42	18	<5	20	84	113	13	<10
91RME-0095	5.86	98.68	52.81	84.57	66	50	16	42	13	256	141	13	<10
91RME-0100	0.29	99.30	78.94	6.60	<10	14	6	7	2	7	5	<10	<10
91RME-0106	0.35	99.34	70.79	7.72	<10	<5	6	8	<2	13	-5	<10	<10
91RME-0107	5.65	99.95	72.93	71.11	56	33	11	22	14	104	179	24	<10
91RME-0108	5.38	98.59	58.24	69.78	58	57	27	43	13	270	105	<10	<10
91RME-0109	8.28	98.80	41.97	106.69	92	70	38	52	13	446	136	<10	24
91RME-0110	5.89	98.82	68.25	59.52	44	34	14	42	13	78	175	32	<10
91RME-0113	2.92	96.96	81.00	207.09	29	21	9	13	7	102	62	<10	<10
91RME-0114	1.31	99.13	67.02	41.64	17	17	8	13	4	46	132	39	<10
91RME-0118	0.69	100.04	85.67	29.23	<10	9	6	8	<2	6	20	16	<10
91RME-0120	2.25	99.22	68.52	64.66	20	16	7	6	5	25	70	<10	<10
91RME-0126	0.50	99.99	98.65	NC	<10	5	<5	<5	<2	10	13	<10	<10
91RME-0133	13.13	99.45	16.35	81.99	74	38	18	6	23	148	118	17	<10
91RME-0134	0.31	99.91	70.85	8.24	<10	8	7	9	<2	8	32	<10	<10
91RME-0135	4.90	99.48	71.17	69.58	40	27	12	<5	12	70	127	12	<10
91RME-0136	4.21	99.44	70.78	53.84	44	23	10	18	11	69	119	26	<10
91RME-1030	0.65	99.66	98.26	NC	<10	<5	<5	<5	<2	<5	8	<10	<10
91RME-1039	2.87	99.51	68.53	67.28	18	16	14	30	6	39	825	70	<10
91RME-1040	10.26	100.10	46.48	57.92	100	34	25	5	21	144	202	<10	<10
91RME-0175	7.24	99.65	28.38	66.78	73	27	13	<5	13	71	116	11	NA
91RME-0181	2.38	99.13	16.29	58.37	11	<5	<5	<5	<2	6	19	<10	NA
91RME-0182	10.07	99.30	34.91	58.22	<10	9	27	<5	22	229	152	<10	NA
91RME-1114	3.60	99.55	19.51	63.47	26	<5	<5	5	<2	<5	27	<10	NA
91RME-1115	3.89	99.28	24.81	60.84	24	<5	<5	<5	7	16	57	<10	NA
91RME-1116	6.99	98.72	61.60	54.74	224	85	26	27	25	137	74	<10	NA
91RME-0014	1.91	99.28	41.49	64.84	NA	8	5	8	2	16	37	<10	<6
91RME-0110	5.41	97.75	68.84	60.57	NA	33	16	39	12	82	322	37	<6
91RME-0188B	10.98	97.76	45.49	71.98	NA	44	22	<5	17	219	59	<10	<6
91RME-0188C	7.68	98.10	46.14	73.45	NA	21	13	<5	13	128	69	<10	<6
91RME-0188E	7.69	97.37	48.60	65.04	NA	22	24	<5	14	139	106	<10	<6
91RME-0190	2.78	100.71	7.15	60.88	NA	<5	<5	<5	1	26	8	<10	<6
91RME-0206	2.29	100.17	51.99	65.90	NA	8	7	104	5	34	72	<10	<6
91RME-0232	8.86	97.86	35.04	84.09	NA	42	16	193	23	147	71	<10	<6
91RME-0234	2.77	99.87	21.66	60.20	NA	<5	<5	7	2	10	21	<10	<6
91RME-1016	2.81	100.19	49.57	63.28	NA	10	6	<5	5	47	37	<10	<6
91RME-1023	6.81	99.65	16.42	68.17	NA	<5	7	<5	15	<5	39	<10	<6
91RME-1068	7.16	99.31	51.05	45.93	NA	30	16	7	13	86	167	<10	<6

Appendix 1. continued.

Sample Name	As (ppm)	W (ppm)	Cd (ppm)	Sb (ppm)	Li (ppm)	B (ppm)	Be (ppm)	Ba (ppm)	Rb (ppm)	Sr (ppm)	Nb (ppm)	Zr (ppm)	Y (ppm)	Th (ppm)
90RME-0206	<6	<35	NA	NA	NA	NA	<3	286	23	640	8	54	14	<10
91RME-0002	NA	<35	<2	<0.1	<3	27	<1	101	7	80	<5	15	2	<10
91RME-0021	NA	<35	<2	0.7	13	5	2.0	450	85	181	13	509	82	<10
91RME-0050	NA	<35	<2	<0.1	23	22	1.0	195	82	329	7	156	10	<10
91RME-0091	NA	<35	<2	0.3	85	104	2.0	595	139	268	14	163	27	<10
91RME-0092	NA	<35	<2	<0.1	21	162	<1	240	60	91	20	228	36	<10
91RME-0093	NA	<35	<2	<0.1	18	227	1.0	560	72	173	16	284	8	13
91RME-0094	NA	<35	<2	0.7	22	82	2.0	695	159	118	12	225	36	<10
91RME-0095	NA	<35	<2	2.2	64	131	2.0	620	129	331	8	178	26	16
91RME-0100	NA	<35	<2	<0.1	9	5	<1	350	<5	>2000	<5	<5	3	<10
91RME-0106	NA	<35	<2	<0.1	7	3	<1	310	<5	>2000	5	5	5	<10
91RME-0107	NA	<35	<2	0.7	94	129	2.0	854	126	225	10	187	24	<10
91RME-0108	NA	<35	<2	1.3	54	160	2.0	490	121	146	9	178	25	<10
91RME-0109	NA	<35	<2	7.3	59	107	2.0	130	103	329	7	158	31	<10
91RME-0110	NA	<35	<2	2.4	96	93	2.0	405	106	219	15	173	21	<10
91RME-0113	NA	<35	<2	0.5	42	66	<1	540	70	823	3	69	36	<10
91RME-0114	NA	<35	<2	1.3	21	36	<1	1425	27	1205	<5	28	9	<10
91RME-0118	NA	<35	<2	0.5	9	12	<1	280	10	195	6	19	3	<10
91RME-0120	NA	<35	<2	0.3	22	55	<1	250	18	381	5	59	14	<10
91RME-0126	NA	<35	<2	0.5	25	5	<1	295	<5	26	<5	12	1	<10
91RME-0133	NA	<35	<2	<0.1	80	92	2.0	790	114	35	14	219	20	15
91RME-0134	NA	<35	<2	0.5	7	5	<1	500	<5	>2000	<5	<5	4	10
91RME-0135	NA	<35	<2	0.7	78	87	1.0	415	107	243	14	167	20	<10
91RME-0136	NA	<35	<2	0.4	69	70	1.0	610	84	298	9	137	28	<10
91RME-1030	NA	<35	<2	<0.1	5	4	<1	130	<5	114	<5	11	1	<10
91RME-1039	NA	<35	3	0.5	45	348	<1	315	45	136	<5	120	7	<10
91RME-1040	NA	<35	<2	2.0	40	36	<1	735	75	340	10	180	36	<10
91RME-0175	NA	<35	<2	1.0	35	71	2.0	430	90	97	12	420	26	<10
91RME-0181	NA	<35	<2	1.0	9	6	3.0	265	188	45	33	743	39	21
91RME-0182	NA	<35	<2	2.5	24	12	<1	345	62	526	11	162	32	<10
91RME-1114	NA	<35	<2	1.6	8	20	6.0	195	62	197	18	757	79	<10
91RME-1115	NA	<35	<2	0.4	12	9	2.0	420	90	245	15	404	48	<10
91RME-1116	NA	<35	<2	0.7	12	24	<1	140	28	849	8	109	19	<10
91RME-0014	<6	<35	NA	NA	NA	8	1.3	270	55	116	3	112	9	<10
91RME-0110	13	<35	NA	NA	NA	119	1.7	426	90	209	9	165	30	<10
91RME-0188B	<6	<35	NA	NA	NA	31	0.9	1225	135	67	14	293	33	<10
91RME-0188C	<6	<35	NA	NA	NA	152	0.8	1190	84	54	11	245	34	<10
91RME-0188E	<6	<35	NA	NA	NA	25	1.0	571	80	87	8	188	23	<10
91RME-0190	<6	<35	NA	NA	NA	11	1.6	288	93	44	26	608	91	15
91RME-0206	7	<35	NA	NA	NA	24	1.1	432	30	237	8	131	6	<10
91RME-0232	<6	<35	NA	NA	NA	184	1.0	491	101	58	14	223	48	<10
91RME-0234	7	<35	NA	NA	NA	10	2.5	278	113	39	27	631	93	17
91RME-1016	16	<35	NA	NA	NA	69	1.1	644	43	283	7	156	5	<10
91RME-1023	<6	<35	NA	NA	NA	16	1.8	889	42	67	13	429	64	<10
91RME-1068	16	<35	NA	NA	NA	61	1.3	884	32	453	8	204	22	<10

Appendix 1. continued.

Sample Name	La (ppm)	Ce (ppm)	Pr (ppm)	Nd (ppm)	Sm (ppm)	Eu (ppm)	Gd (ppm)	Tb (ppm)	Dy (ppm)	Ho (ppm)	Er (ppm)	Tm (ppm)	Yb (ppm)	Lu (ppm)	Total REE (ppm)
90RME-0206	10.42	23.38	3.31	14.36	3.26	1.91	3.06	0.42	2.32	0.43	1.12	0.14	0.88	0.13	65.1
91RME-0002	0.80	1.50	0.20	0.90	0.24	0.08	0.23	0.04	0.30	0.06	0.16	<0.03	0.16	<0.04	4.7
91RME-0021	31.00	71.20	9.80	46.30	12.11	3.19	13.05	2.23	14.03	3.08	8.15	1.30	8.44	1.26	225.1
91RME-0050	17.50	35.30	4.30	16.50	3.22	0.82	2.50	0.35	1.95	0.37	1.00	0.16	1.04	0.16	85.2
91RME-0091	25.60	53.20	6.50	27.60	5.45	1.18	4.74	0.72	4.52	0.99	2.65	0.41	2.77	0.41	136.7
91RME-0092	22.50	57.80	6.00	24.60	5.26	1.10	5.06	0.84	6.11	1.38	3.80	0.61	4.08	0.64	139.8
91RME-0093	55.70	122.80	14.50	56.90	9.84	2.08	5.62	0.59	2.37	0.34	0.71	0.09	0.66	0.12	272.3
91RME-0094	25.10	63.20	6.30	26.90	6.20	1.57	5.94	0.96	6.15	1.31	3.69	0.58	3.68	0.54	152.1
91RME-0095	29.30	62.10	7.20	29.50	6.03	1.34	5.15	0.76	4.72	0.91	2.58	0.41	2.76	0.43	153.2
91RME-0100	1.40	2.70	0.30	1.40	0.33	<0.07	0.28	0.03	0.32	0.06	0.19	<0.03	0.20	<0.04	7.2
91RME-0106	2.60	4.60	0.50	2.20	0.44	0.09	0.46	0.06	0.47	0.10	0.29	0.04	0.35	0.05	12.2
91RME-0107	27.80	60.00	7.00	28.80	6.10	1.22	5.41	0.78	4.35	0.87	2.24	0.36	2.56	0.39	147.9
91RME-0108	22.80	49.20	6.10	25.50	5.24	1.03	4.44	0.68	4.30	0.88	2.49	0.38	2.68	0.42	126.1
91RME-0109	34.40	85.30	8.80	35.00	7.11	1.37	6.10	0.90	5.40	1.11	2.95	0.44	3.04	0.48	192.4
91RME-0110	25.60	54.60	6.60	26.00	5.60	1.09	4.87	0.74	4.09	0.78	2.00	0.33	2.38	0.37	135.0
91RME-0113	15.50	32.40	4.40	19.10	4.78	0.91	5.55	0.88	5.88	1.27	3.47	0.54	3.93	0.61	99.2
91RME-0114	4.90	10.80	1.40	6.00	1.37	0.21	1.26	0.18	1.28	0.26	0.77	0.10	0.84	0.12	29.5
91RME-0118	2.40	3.20	0.50	1.90	0.41	0.11	0.36	0.05	0.34	0.07	0.21	<0.03	0.17	0.00	9.7
91RME-0120	10.90	20.20	2.60	11.40	2.33	0.58	2.23	0.31	2.03	0.42	1.13	0.16	1.07	0.18	55.5
91RME-0126	0.80	0.90	0.00	0.60	<0.15	<0.07	<0.14	<0.03	<0.13	<0.03	<0.10	<0.03	<0.11	<0.04	2.3
91RME-0133	25.60	50.70	5.60	22.90	4.57	1.19	4.17	0.60	3.62	0.76	2.26	0.38	2.90	0.45	125.7
91RME-0134	2.20	4.20	0.50	2.10	0.49	0.08	0.46	0.05	0.42	0.08	0.27	0.03	0.32	<0.04	11.2
91RME-0135	23.70	50.20	6.10	24.80	5.11	0.99	4.45	0.64	3.75	0.70	2.04	0.31	2.19	0.35	125.3
91RME-0136	19.40	41.60	5.10	21.20	4.59	1.01	4.54	0.69	4.68	0.96	2.64	0.42	2.76	0.43	110.0
91RME-1030	0.80	1.30	0.20	0.60	0.16	<0.07	<0.14	<0.03	<0.13	<0.03	<0.10	<0.03	<0.11	<0.04	3.1
91RME-1039	10.80	23.60	2.70	11.00	2.19	0.58	1.77	0.22	1.29	0.23	0.60	0.08	0.61	0.08	55.8
91RME-1040	18.00	41.60	5.20	23.50	6.03	1.77	6.23	0.98	6.13	1.26	3.43	0.53	3.51	0.53	118.7
91RME-0175	28.50	59.00	7.80	33.50	7.20	1.61	6.20	0.91	5.39	1.00	2.65	0.43	2.90	0.46	157.5
91RME-0181	56.20	121.40	15.10	63.80	13.77	1.02	10.77	1.44	7.68	1.33	3.65	0.57	4.08	0.60	301.4
91RME-0182	24.10	54.90	7.20	32.20	6.61	2.20	5.90	0.90	5.66	1.13	3.07	0.45	2.95	0.44	147.7
91RME-1114	49.10	108.70	13.80	60.10	12.84	1.43	12.19	2.02	13.29	2.88	8.36	1.29	8.75	1.24	296.0
91RME-1115	38.10	89.80	11.10	47.60	9.74	2.23	8.86	1.40	8.80	1.74	4.64	0.69	4.40	0.65	229.8
91RME-1116	12.60	31.00	4.30	20.00	4.29	1.48	4.08	0.59	3.69	0.68	1.77	0.25	1.62	0.22	86.6
91RME-0014	17.32	33.95	3.90	13.23	2.44	0.67	2.23	0.33	1.64	0.30	0.75	0.12	0.72	0.11	77.7
91RME-0110	26.17	56.09	7.14	26.88	5.75	1.17	5.34	0.81	4.26	0.86	2.26	0.35	2.45	0.38	139.9
91RME-0188B	28.25	66.23	8.52	32.69	6.98	2.05	6.64	1.01	5.40	1.15	3.06	0.44	2.79	0.39	165.6
91RME-0188C	27.18	62.80	8.35	31.68	6.54	1.87	5.98	0.92	4.85	0.99	2.60	0.39	2.46	0.39	157.0
91RME-0188E	15.95	37.46	5.10	19.96	4.47	1.34	4.36	0.67	4.01	0.86	2.38	0.38	2.32	0.35	99.6
91RME-0190	68.07	145.88	20.24	75.94	15.65	1.45	10.55	1.24	4.98	0.92	2.42	0.38	2.61	0.41	350.7
91RME-0206	25.42	52.48	6.34	22.41	3.63	1.04	2.69	0.34	1.41	0.27	0.66	0.09	0.53	0.08	117.4
91RME-0232	38.84	82.80	10.83	40.17	8.28	1.61	8.01	1.30	7.73	1.71	4.76	0.76	4.84	0.75	212.4
91RME-0234	56.58	118.66	16.42	61.82	12.46	0.98	10.84	1.46	6.94	1.39	3.79	0.57	3.86	0.63	296.4
91RME-1016	27.55	57.45	7.15	25.05	3.98	1.21	2.88	0.37	1.53	0.26	0.67	0.09	0.53	0.09	128.8
91RME-1023	37.18	82.23	12.59	50.54	12.09	3.66	11.49	1.72	9.06	1.77	4.99	0.81	5.48	0.95	234.6
91RME-1068	31.43	66.43	9.00	32.62	6.17	1.76	5.26	0.81	4.05	0.82	2.09	0.32	1.97	0.30	163.0

Appendix 1. continued.

Sample Name	Easting (m)	Northing (m)	Township	Rock Type	Formation or Pluton	SiO_2 (wt %)	TiO_2 (wt %)	Al_2O_3 (wt %)
91RME-1141	318750	4976350	Effingham	ultramafic	Killer Creek suite	41.37	2.30	6.80
92RME-0030	354730	4990100	South Canonto	pyroxenite, host rock	Summit Lake mine	45.68	0.22	5.45
92RME-0049	352720	4985400	Palmerston	dolomite marble	Mississagagon	4.52	0.00	0.19
92RME-0057	352280	4984200	Palmerston	calcite marble	Mississagagon	36.20	0.29	6.89
92RME-0061	350660	4983150	Clarendon	dolomite marble	Mississagagon	0.82	0.01	0.21
92RME-0068	349700	4984760	Clarendon	garnet-biotite-sillimanite schist	Myer Cave	56.42	1.24	22.06
92RME-0082	349750	4984910	Clarendon	kyanite schist	Bishop Corners	59.08	1.26	17.44
92RME-0094	360418	4987305	Palmerston	carbonate-amphibole rock	Mississagagon	45.16	1.01	15.27
92RME-0098	349680	4990710	South Canonto	tonalite gneiss	Elzevir suite	70.96	0.17	16.48
92RME-0104	360285	4987850	Palmerston	muscovite pelite	Bishop Corners?	66.62	0.33	16.56
92RME-0107	360230	4987650	Palmerston	dacite	Mazinaw Lake	57.50	0.65	15.79
92RME-0113	349070	4984880	Clarendon	dacite	Mazinaw Lake	56.46	0.84	18.31
92RME-0123	350340	4985840	Miller	muscovite pelite	Bishop Corners?	72.05	0.30	16.28
92RME-0126	345500	4985350	Miller	felsite	Mazinaw Lake	64.71	1.15	16.21
92RME-0140	343910	4996390	Miller	calcite marble	Mississagagon	1.00	0.02	0.30
92RME-0161	343060	4993630	Miller	semi-pelite	Mississagagon	54.56	1.19	17.40
92RME-0185	354490	4998525	Miller	granite gneiss	Methuen suite	65.31	0.79	15.21
92RME-0187	344175	4998575	Miller	granodiorite gneiss	Elzevir suite	60.89	1.21	15.87
92RME-0190	343540	4998740	Miller	granite gneiss	Methuen suite	73.38	0.17	13.99
92RME-0193	342830	4998180	Miller	granite gneiss	Methuen suite	75.73	0.10	12.04
92RME-0196	344070	4998320	Miller	granodiorite gneiss	Methuen suite	68.87	0.52	14.60
92RME-0198	344235	4998560	Miller	granite gneiss	Methuen suite	69.85	0.47	14.63
92RME-0292	359950	4996135	South Canonto	granite gneiss, augen	Methuen suite	68.81	0.51	13.78
92RME-0400	310678	4973908	Effingham	gabbro, geochron site	Killer Creek suite	48.84	0.22	16.45
92RME-0402	321837	4965395	Anglesea	syenite, geochron site	Skootamatta	59.35	0.76	18.68
92RME-1032	359170	4987790	Palmerston	pelite	Myer Cave	55.25	1.33	19.70
92RME-1039	361500	4989930	Palmerston	garnet-sillimanite schist	Mississagagon	56.91	1.05	16.97
92RME-1046	359650	4987880	Palmerston	conglomerate	Ompah	51.44	1.69	14.57
92RME-1052	360590	4987640	Palmerston	mafic gneiss	Kashwakamak?	46.57	1.07	15.84
92RME-1055	361710	4987710	Palmerston	dolomite marble	Mississagagon	0.30	<0.01	0.10
92RME-1062	356250	4984400	South Canonto	conglomerate	Ompah	68.64	1.01	10.73
93RME-0010	339007	4963814	Barrie	dacite flow, geochron site	Kashwakamak	65.24	0.40	17.19
93RME-0011	333172	4964043	Barrie	dacite dome, geochron site	Kashwakamak	61.67	0.63	16.35
93RME-0012	333639	4966376	Barrie	tonalite, geochron site	Helena stock	65.84	0.44	17.16
93RME-0014	329292	4971124	Barrie	dacite pyroclastic, geochron site	Mazinaw Lake	70.06	0.45	13.69
93RME-0015	351724	4974303	Clarendon	tonalite gneiss, geochron site	Cross Lake	63.60	0.56	17.70
93RME-0016	335415	4985400	Abinger	granite gneiss, geochron site	Abinger	78.26	0.07	12.01
93RME-0017	338971	4975887	Clarendon	granite gneiss, geochron site	Norway Lake	72.89	0.26	12.66
93RME-0020	354211	4995651	South Canonto	calc-silicate gneiss, geochron site	Mississagagon	50.94	0.59	12.71
93RME-0021	354211	5995651	South Canonto	calcite marble	Mississagagon	20.21	0.13	4.27
94RME-0064	366000	4995825	Lavant	pelite	Bishop Corners	61.22	1.06	15.11
94RME-0067	334237	4968604	Barrie	calcite marble clast	Mississagagon in Myer Cave	3.77	0.03	1.41
94RME-0068	334237	4968604	Barrie	dolomite marble clast	Mississagagon in Myer Cave	2.36	0.01	1.13
94RME-0069	327536	4966886	Barrie	calcite marble, siliceous	Mississagagon	47.06	0.47	13.78

Appendix 1. continued.

Sample Name	Fe_2O_3 (wt %)	FeO (wt %)	MnO (wt %)	MgO (wt %)	CaO (wt %)	Na_2O (wt %)	K_2O (wt %)	P_2O_5 (wt %)	LOI (wt %)	S (wt %)	H_2O+ (wt %)	CO_2 (wt %)
91RME-1141	7.30	14.01	0.30	16.06	6.72	0.47	0.05	0.21	2.00	<0.03	NA	<0.30
92RME-0030	2.73	2.41	0.11	14.04	23.87	0.18	0.16	0.07	3.15	0.04	NA	2.95
92RME-0049	0.19	<0.20	0.03	21.23	29.53	0.01	0.03	0.01	44.01	<0.03	NA	42.40
92RME-0057	1.45	0.71	0.05	7.79	24.27	0.89	4.94	0.07	15.74	0.65	NA	15.30
92RME-0061	0.11	<0.20	0.04	20.38	31.50	0.00	0.02	0.00	46.97	<0.03	NA	45.30
92RME-0068	2.79	7.65	0.11	1.68	0.33	0.20	2.88	0.22	2.35	0.03	NA	2.34
92RME-0082	5.91	3.86	0.09	1.64	3.12	3.14	2.32	0.25	0.98	<0.03	NA	0.38
92RME-0094	3.13	7.93	0.17	7.07	12.23	2.69	0.66	0.10	2.92	0.44	NA	3.06
92RME-0098	0.31	1.15	0.03	0.76	2.91	5.54	1.48	0.08	0.36	<0.03	NA	<0.30
92RME-0104	1.69	2.36	0.21	1.73	1.50	1.44	4.13	0.10	2.03	<0.03	NA	<0.30
92RME-0107	5.27	1.08	0.08	4.56	3.84	0.46	6.48	0.14	2.38	<0.03	NA	0.44
92RME-0113	4.35	2.46	0.09	2.52	3.71	5.47	3.38	0.28	2.03	<0.03	NA	1.12
92RME-0123	2.42	<0.20	0.05	0.62	0.16	1.98	3.97	0.03	1.91	<0.03	NA	<0.30
92RME-0126	1.21	4.22	0.11	1.21	2.54	5.40	1.61	0.35	1.21	<0.03	NA	0.63
92RME-0140	0.14	<0.20	0.01	3.88	50.58	0.04	0.05	0.01	43.82	<0.03	NA	42.60
92RME-0161	5.01	2.63	0.17	3.89	2.90	0.31	5.47	0.29	3.68	<0.03	NA	<0.30
92RME-0185	1.28	3.57	0.10	1.14	2.75	4.33	3.35	0.16	0.45	<0.03	NA	<0.30
92RME-0187	2.24	4.68	0.13	1.93	4.95	5.09	2.26	0.29	0.47	<0.03	NA	<0.30
92RME-0190	0.75	1.16	0.03	0.21	0.72	4.26	3.76	0.03	0.35	<0.03	NA	<0.30
92RME-0193	1.14	0.90	0.03	0.09	0.51	3.71	4.67	0.02	0.36	<0.03	NA	<0.30
92RME-0196	1.07	2.39	0.05	0.70	2.01	3.90	4.21	0.11	0.40	<0.03	NA	<0.30
92RME-0198	1.27	2.29	0.06	0.63	2.01	3.59	4.61	0.10	0.33	<0.03	NA	<0.30
92RME-0292	1.64	3.59	0.09	0.32	1.73	2.91	5.44	0.11	0.28	<0.03	NA	<0.30
92RME-0400	1.19	6.12	0.14	10.19	12.06	2.23	0.25	0.03	0.65	<0.03	NA	<0.30
92RME-0402	2.11	2.15	0.08	1.28	2.34	5.58	5.90	0.33	1.06	0.03	NA	0.50
92RME-1032	3.15	11.64	0.04	1.67	0.47	0.20	2.80	0.21	1.36	<0.03	NA	<0.30
92RME-1039	6.19	6.68	0.04	2.38	0.77	0.51	3.84	0.23	2.05	0.06	NA	<0.30
92RME-1046	5.92	6.31	0.21	5.33	9.51	1.31	0.79	0.20	0.92	<0.03	NA	<0.30
92RME-1052	2.84	8.72	0.19	7.93	11.87	2.11	0.21	0.11	0.83	0.03	NA	<0.30
92RME-1055	0.13	<0.20	0.02	21.21	30.37	<0.01	0.03	<0.01	47.52	<0.03	NA	45.90
92RME-1062	3.60	0.90	0.06	1.30	5.63	0.85	3.32	0.14	2.49	<0.03	NA	1.60
93RME-0010	1.28	2.30	0.07	1.97	3.91	5.15	1.31	0.25	0.71	<0.03	0.77	<0.30
93RME-0011	1.52	3.64	0.07	4.60	4.85	3.80	0.70	0.19	1.09	<0.03	1.54	<0.30
93RME-0012	0.95	1.84	0.04	1.28	2.84	4.58	2.48	0.16	1.83	0.16	1.19	0.92
93RME-0014	2.19	2.02	0.07	0.97	1.13	4.03	3.63	0.45	0.11	<0.03	0.57	0.76
93RME-0015	1.50	2.46	0.06	1.76	4.75	5.10	1.61	0.22	0.54	<0.03	0.77	<0.30
93RME-0016	1.06	0.41	0.02	0.10	0.36	3.49	4.36	0.02	0.20	<0.03	0.33	<0.30
93RME-0017	2.52	1.02	0.03	0.36	0.98	3.86	4.41	<0.02	0.88	<0.03	0.41	0.57
93RME-0020	0.67	4.90	0.08	3.45	15.68	3.66	1.36	0.17	5.61	0.03	0.44	5.50
93RME-0021	0.39	2.43	0.07	2.53	38.70	0.83	0.38	0.07	29.05	0.06	0.38	28.70
94RME-0064	7.11	2.64	0.06	2.01	0.33	0.22	2.05	0.20	4.85	0.01	4.74	<0.10
94RME-0067	1.00	0.00	0.06	10.59	39.24	0.22	0.03	<0.05	42.97	0.02	NA	43.10
94RME-0068	0.44	0.00	0.07	3.12	47.79	0.09	<0.02	<0.05	42.79	0.01	NA	42.80
94RME-0069	2.60	0.00	0.04	1.82	15.62	1.48	2.84	0.47	12.76	0.02	NA	12.10

Appendix I. continued.

Sample Name	FeO (wt %)	Total (wt %)	Mg Number	CIA	Cr (ppm)	Ni (ppm)	Co (ppm)	Cu (ppm)	Sc (ppm)	V (ppm)	Zn (ppm)	Pb (ppm)	Mo (ppm)
91RME-1141	20.58	97.59	58.18	48.43	NA	380	96	<5	25	341	155	<10	<6
92RME-0030	4.87	98.11	83.72	20.40	NA	13	7	6	6	37	770	<10	<6
92RME-0049	0.17	99.75	99.55	0.64	NA	7	<5	<5	<1	16	10	<10	<6
92RME-0057	2.01	99.94	87.33	31.77	NA	20	5	8	5	37	29	<10	<6
92RME-0061	0.10	100.06	99.73	0.66	NA	8	<5	<5	<1	16	10	<10	<6
92RME-0068	10.16	97.96	22.77	95.37	NA	31	27	17	23	156	172	<10	<6
92RME-0082	9.18	99.09	24.16	68.01	NA	33	17	<5	21	141	49	<10	<6
92RME-0094	10.75	98.78	53.98	54.95	NA	94	51	122	39	247	78	<10	<6
92RME-0098	1.43	100.23	48.67	62.40	NA	<5	<5	<5	2	12	47	11	<6
92RME-0104	3.88	98.70	44.28	70.08	NA	11	11	<5	5	32	46	<10	<6
92RME-0107	5.82	98.23	58.27	60.42	NA	14	18	117	15	106	80	<10	<6
92RME-0113	6.37	99.90	41.34	61.55	NA	47	16	<5	11	60	25	<10	<6
92RME-0123	2.18	99.77	33.67	72.71	NA	10	<5	<5	1	7	19	<10	<6
92RME-0126	5.31	99.93	28.89	64.49	NA	<5	5	<5	12	16	108	<10	<6
92RME-0140	0.13	99.85	98.21	3.59	NA	<5	<5	<5	<1	6	5	<10	<6
92RME-0161	7.14	97.50	49.28	66.72	NA	42	27	<5	19	139	314	<10	<6
92RME-0185	4.72	98.44	30.09	59.32	NA	5	12	<5	7	65	93	<10	<6
92RME-0187	6.70	100.01	33.95	56.34	NA	7	15	<5	13	98	118	<10	<6
92RME-0190	1.83	98.81	16.95	61.55	NA	<5	<5	<5	1	<5	45	<10	<6
92RME-0193	1.93	99.30	7.69	57.53	NA	<5	<5	<5	<1	-5	51	<10	<6
92RME-0196	3.35	98.83	27.13	59.06	NA	<5	7	<5	6	29	61	<10	<6
92RME-0198	3.43	99.84	24.65	58.90	NA	<5	7	<5	5	32	61	15	<6
92RME-0292	5.07	99.21	10.12	57.75	NA	<5	<5	<5	11	8	152	<10	<6
92RME-0400	7.19	98.37	71.64	53.08	NA	172	45	73	39	156	45	<10	<6
92RME-0402	4.05	99.65	36.05	58.38	NA	<5	8	6	5	38	74	<10	<6
92RME-1032	14.47	97.82	17.06	85.02	NA	28	17	9	22	147	112	<10	<6
92RME-1039	12.25	97.68	25.73	76.82	NA	54	22	51	21	131	165	30	<6
92RME-1046	11.64	98.20	44.95	55.65	NA	59	39	33	38	221	105	<10	<6
92RME-1052	11.28	98.32	55.63	52.75	NA	92	51	59	42	270	87	<10	<6
92RME-1055	0.12	99.68	99.69	0.33	NA	9	5	<5	<1	16	34	<10	<6
92RME-1062	4.14	98.67	35.89	56.68	NA	13	9	<5	9	84	47	<10	<6
93RME-0010	3.45	99.78	50.43	62.37	NA	16	10	<5	7	49	59	10	<6
93RME-0011	5.01	99.11	62.09	63.62	NA	51	19	10	14	82	75	11	<6
93RME-0012	2.69	99.60	45.85	65.65	NA	9	6	32	6	49	36	<7	<6
93RME-0014	3.99	98.80	30.23	63.03	NA	<5	<5	<5	4	17	67	<7	<6
93RME-0015	3.81	99.86	45.16	60.70	NA	11	12	27	8	60	79	7	<6
93RME-0016	1.36	100.36	11.56	59.40	NA	<5	<5	<5	<1	<5	52	<7	<6
93RME-0017	3.29	99.87	16.33	59.33	NA	<5	<5	<5	2	7	45	9	<6
93RME-0020	5.50	99.85	52.78	45.54	NA	28	20	20	16	114	88	<7	<6
93RME-0021	2.78	99.12	61.86	27.58	NA	13	49	49	6	35	51	13	<6
94RME-0064	9.04	96.87	28.39	85.34	64	60	30	<5	16	143	145	NA	<8
94RME-0067	0.90	99.34	95.45	3.45	2	13	<5	<5	1	17	24	NA	<8
94RME-0068	0.40	97.81	93.36	2.31	<2	7	<5	<5	<1	8	12	NA	<8
94RME-0069	2.34	98.96	58.11	63.74	36	26	7	42	7	41	54	NA	<8

Appendix 1. continued.

Sample Name	As (ppm)	W (ppm)	Cd (ppm)	Sb (ppm)	Li (ppm)	B (ppm)	Be (ppm)	Ba (ppm)	Rb (ppm)	Sr (ppm)	Nb (ppm)	Zr (ppm)	Y (ppm)	Th (ppm)
91RME-1141	<6	<35	NA	NA	NA	3	<1	35	<5	11	4	117	25	<10
92RME-0030	<6	<35	NA	NA	NA	51	2.0	<30	7	57	3	117	9	11
92RME-0049	<6	<35	NA	NA	NA	5	<1	<30	5	316	<3	12	<5	<10
92RME-0057	<6	<35	NA	NA	NA	19	0.6	205	40	354	5	80	9	12
92RME-0061	<6	<35	NA	NA	NA	3	<1	<30	<5	164	<3	15	<5	<10
92RME-0068	<6	<35	NA	NA	NA	33	2.3	281	116	37	15	208	48	<10
92RME-0082	<6	<35	NA	NA	NA	203	2.0	514	66	343	10	276	49	<10
92RME-0094	182	<35	NA	NA	NA	181	<1	83	16	180	3	61	21	<10
92RME-0098	<6	<35	NA	NA	NA	24	3.0	200	95	489	5	76	7	<10
92RME-0104	<6	<35	NA	NA	NA	244	0.9	216	83	87	3	125	5	<10
92RME-0107	<6	<35	NA	NA	NA	117	0.5	259	63	102	5	114	12	<10
92RME-0113	<6	<35	NA	NA	NA	23	1.1	1121	73	208	7	172	16	<10
92RME-0123	<6	<35	NA	NA	NA	118	0.7	318	55	40	<3	114	<5	<10
92RME-0126	<6	<35	NA	NA	NA	8	2.0	350	48	192	14	362	59	<10
92RME-0140	<6	<35	NA	NA	NA	7	<1	75	<5	558	3	11	5	14
92RME-0161	<6	<35	NA	NA	NA	162	2.3	1438	265	166	7	192	25	<10
92RME-0185	<6	<35	NA	NA	NA	10	1.6	436	164	153	9	215	32	11
92RME-0187	<6	<35	NA	NA	NA	10	2.2	354	89	198	12	260	61	<10
92RME-0190	<6	<35	NA	NA	NA	9	4.0	146	140	32	19	316	119	20
92RME-0193	<6	<35	NA	NA	NA	9	5.7	60	195	16	29	280	152	28
92RME-0196	<6	<35	NA	NA	NA	8	2.0	502	153	145	10	252	53	11
92RME-0198	<6	<35	NA	NA	NA	11	1.9	514	168	153	8	274	42	14
92RME-0292	<6	<35	NA	NA	NA	4	4.2	772	185	80	42	747	179	13
92RME-0400	<6	<35	NA	NA	NA	6	<1	46	5	144	<3	18	6	<10
92RME-0402	<6	<35	NA	NA	NA	11	1.4	1739	84	1365	9	575	20	<10
92RME-1032	7	<35	NA	NA	NA	43	1.6	725	100	30	15	216	29	<10
92RME-1039	18	<35	NA	NA	NA	299	2.0	2277	142	36	13	188	44	<10
92RME-1046	NA	<35	NA	NA	NA	16	0.8	190	16	182	8	120	35	<10
92RME-1052	NA	<35	NA	NA	NA	5	<1	75	7	151	3	61	21	<10
92RME-1055	NA	<35	NA	NA	NA	11	<1	<30	<5	74	<3	16	<5	<10
92RME-1062	NA	<35	NA	NA	NA	74	1.3	442	80	152	3	262	28	<10
93RME-0010	<6	<35	NA	NA	NA	6	1.4	NA	33	615	8	183	17	<10
93RME-0011	<6	<35	NA	NA	NA	8	1.0	NA	13	487	6	135	13	<10
93RME-0012	<6	<35	NA	NA	NA	22	1.1	NA	41	319	8	129	8	<10
93RME-0014	<6	<35	NA	NA	NA	5	5.7	NA	86	57	15	631	119	<10
93RME-0015	<6	<35	NA	NA	NA	8	1.3	NA	33	734	7	153	10	<10
93RME-0016	<6	<35	NA	NA	NA	3	2.7	NA	114	38	13	218	79	13
93RME-0017	<6	<35	NA	NA	NA	27	3.5	NA	115	38	24	665	107	16
93RME-0020	<6	<35	NA	NA	NA	7	0.7	NA	31	470	3	94	22	<10
93RME-0021	<6	<35	NA	NA	NA	7	0.5	NA	17	599	3	46	22	<10
94RME-0064	NA	<35	NA	NA	NA	NA	<3	327	92	34	10	179	35	<3
94RME-0067	NA	<35	NA	NA	NA	NA	0.3	15	3	303	2	24	7	<3
94RME-0068	NA	<35	NA	NA	NA	NA	0.3	58	3	409	3	22	3	<3
94RME-0069	NA	<35	NA	NA	NA	NA	1.3	441	65	348	8	148	12	NA

Appendix 1. continued.

Sample Name	La (ppm)	Ce (ppm)	Pr (ppm)	Nd (ppm)	Sm (ppm)	Eu (ppm)	Gd (ppm)	Tb (ppm)	Dy (ppm)	Ho (ppm)	Er (ppm)	Tm (ppm)	Yb (ppm)	Lu (ppm)	Total REE (ppm)
91RME-1141	6.58	18.37	2.97	14.27	4.10	1.02	4.78	0.82	4.92	1.05	2.77	0.39	2.60	0.40	65.0
92RME-0030	5.62	10.00	1.30	4.69	1.13	0.12	1.23	0.23	1.52	0.33	0.90	0.12	0.79	0.14	28.1
92RME-0049	0.40	0.70	0.12	0.35	0.08	<0.05	0.07	<0.05	0.06	<0.05	<0.05	<0.05	<0.05	<0.05	1.8
92RME-0057	10.55	20.76	2.82	10.35	2.11	0.63	2.15	0.33	1.85	0.41	1.07	0.16	1.04	0.18	54.4
92RME-0061	0.69	1.27	0.14	0.52	0.11	0.00	0.11	<0.05	0.09	<0.05	0.06	<0.05	0.05	<0.05	3.0
92RME-0068	42.99	91.71	13.02	48.82	10.40	2.26	9.68	1.45	7.92	1.64	4.62	0.75	5.43	0.93	241.6
92RME-0082	27.50	60.91	8.61	34.78	7.71	2.10	6.37	0.88	4.00	0.71	1.81	0.28	2.02	0.36	158.0
92RME-0094	2.00	6.21	1.11	5.97	2.14	0.88	2.90	0.54	3.54	0.81	2.17	0.32	2.12	0.32	31.0
92RME-0098	11.87	24.91	3.20	10.71	2.00	0.53	1.71	0.26	1.36	0.29	0.85	0.14	1.02	0.17	59.0
92RME-0104	11.79	23.78	2.90	10.35	2.06	0.70	1.76	0.27	1.43	0.29	0.75	0.10	0.68	0.11	57.0
92RME-0107	7.79	17.23	2.40	9.63	2.36	0.84	2.59	0.43	2.52	0.56	1.56	0.23	1.61	0.26	50.0
92RME-0113	19.45	42.23	5.95	22.69	4.60	1.46	4.25	0.62	2.95	0.58	1.49	0.21	1.41	0.23	108.1
92RME-0123	3.05	5.16	0.64	2.18	0.44	0.25	0.37	0.05	0.24	0.05	0.13	<0.05	0.14	<0.05	12.7
92RME-0126	35.87	81.20	11.99	48.45	10.76	2.92	10.10	1.54	7.73	1.44	3.48	0.49	3.27	0.55	219.8
92RME-0140	3.01	2.24	0.58	2.18	0.43	0.13	0.58	0.09	0.52	0.14	0.34	0.05	0.26	<0.05	10.6
92RME-0161	29.27	65.47	9.18	37.15	7.30	2.00	6.39	0.97	5.09	1.01	2.43	0.35	2.00	0.29	168.9
92RME-0185	20.93	46.61	5.89	23.11	5.62	1.31	5.58	0.97	5.84	1.31	3.68	0.58	3.79	0.59	125.8
92RME-0187	30.47	68.90	9.76	39.14	9.20	1.72	10.23	1.80	10.56	2.33	6.68	1.02	6.38	0.98	199.2
92RME-0190	61.76	136.26	17.77	68.59	16.36	0.83	17.31	3.16	20.98	4.80	13.64	2.07	12.79	1.72	378.0
92RME-0193	77.03	165.09	22.40	84.17	19.34	0.46	19.52	3.61	23.24	5.32	15.70	2.45	15.61	2.25	456.2
92RME-0196	31.29	63.51	8.50	33.39	7.72	1.21	7.79	1.37	8.77	1.93	5.55	0.85	5.40	0.79	178.1
92RME-0198	59.71	108.34	12.05	38.80	7.08	1.20	7.02	1.21	7.42	1.61	4.57	0.76	4.91	0.76	255.4
92RME-0292	98.44	195.24	32.76	128.36	29.02	4.98	30.91	5.46	31.91	6.95	19.13	2.83	17.68	2.63	606.3
92RME-0400	0.23	0.68	0.15	0.92	0.46	0.29	0.84	0.18	1.30	0.30	0.89	0.13	0.87	0.14	7.4
92RME-0402	66.74	135.86	19.09	69.99	10.90	3.78	8.10	1.03	4.36	0.80	1.84	0.24	1.47	0.22	324.4
92RME-1032	21.52	38.27	4.39	15.19	3.10	1.03	3.55	0.68	4.80	1.11	3.40	0.54	3.54	0.56	101.7
92RME-1039	25.99	63.82	7.97	30.33	6.03	1.50	5.07	0.71	3.07	0.57	1.54	0.25	1.92	0.30	149.1
92RME-1046	8.96	22.52	3.40	16.01	4.32	1.50	5.40	0.96	5.80	1.26	3.50	0.51	3.34	0.49	78.0
92RME-1052	2.13	6.60	1.21	6.38	2.28	0.99	3.28	0.58	3.92	0.86	2.50	0.36	2.34	0.38	33.8
92RME-1055	0.75	1.51	0.18	0.88	0.20	0.05	0.29	0.05	0.32	0.08	0.23	<0.05	0.22	<0.05	4.8
92RME-1062	29.91	63.58	8.33	30.70	6.10	1.42	6.00	0.93	5.03	1.08	3.02	0.45	2.96	0.43	159.9
93RME-0010	48.87	105.45	12.31	42.98	6.83	1.77	4.78	0.61	2.78	0.52	1.39	0.21	1.40	0.21	230.1
93RME-0011	15.90	35.84	4.38	17.14	3.44	1.06	2.89	0.44	2.34	0.47	1.30	0.18	1.18	0.17	86.7
93RME-0012	42.70	84.33	9.87	33.72	5.42	1.57	3.66	0.44	1.63	0.27	0.64	0.08	0.46	0.07	184.9
93RME-0014	59.57	13.07	18.50	75.80	17.88	2.79	16.85	2.68	15.05	3.13	8.98	1.27	8.24	1.31	245.1
93RME-0015	18.60	44.15	5.63	22.31	4.21	1.31	3.23	0.40	1.79	0.32	0.80	0.11	0.64	0.10	103.6
93RME-0016	50.63	114.67	14.86	55.48	12.98	0.82	12.99	2.30	14.33	3.02	8.72	1.26	7.86	1.11	301.0
93RME-0017	56.32	125.40	16.43	62.53	14.28	1.03	13.07	2.22	12.93	2.70	7.94	1.22	8.04	1.17	325.3
93RME-0020	9.04	22.39	3.19	13.96	3.55	0.93	3.45	0.55	3.38	0.73	2.07	0.30	1.92	0.30	65.8
93RME-0021	12.35	26.18	3.44	14.07	3.27	0.86	3.12	0.49	2.94	0.65	1.92	0.29	1.89	0.30	71.8
94RME-0064	13.78	31.39	8.38	33.08	6.74	1.35	5.81	0.76	3.62	0.55	1.27	0.15	0.92	0.14	107.9
94RME-0067	3.43	6.25	0.85	3.41	0.77	0.22	0.87	0.14	0.79	0.16	0.49	0.07	0.36	0.06	17.9
94RME-0068	0.95	1.92	0.27	0.99	0.25	0.10	0.23	0.04	0.22	0.04	0.11	0.02	0.07	0.01	5.2
94RME-0069	21.68	42.13	5.26	19.23	3.40	0.95	2.74	0.41	1.91	0.37	1.03	0.14	0.78	0.13	100.2

Appendix I. continued.

Sample Name	Easting (m)	Northing (m)	Township	Rock Type	Formation or Pluton	SiO$_2$ (wt %)	TiO$_2$ (wt %)	Al$_2$O$_3$ (wt %)
95RME-0001	329745	4972222	Barrie	rhyolite, fiamme outcrop	Mazinaw Lake	73.33	0.30	12.20
95RME-0002	329700	4972222	Barrie	rhyolite, mafic fiamme fragment	Mazinaw Lake	58.84	1.47	15.29
95RME-0003	340670	4995880	Barrie	icelandite, Buffaddison	Mazinaw Lake	56.01	2.17	14.38
95RME-0004	329478	4970690	Barrie	rhyolite or fgr granite	Mazinaw Lake	71.07	0.29	10.91
95RME-0005	326500	4971400	Barrie	icelandite, Highway 41	Mazinaw Lake	59.06	1.50	13.08
95RME-0096	356874	4982787	Clarendon	conlgomerate matrix	Flinton Group	53.87	1.71	13.35
95RME-0097	342398	4980426	Clarendon	schist	Flinton Group	58.59	0.54	15.34
95RME-0098	347360	4977402	Clarendon	mylonite	Mississagagon	63.79	0.49	16.43
95RME-0099	346457	4977565	Clarendon	dolomite marble, alteration zone	Swamp Creek	0.53	0.02	0.19
95RME-0100	347668	4976742	Clarendon	dolomite marble	Myer Cave	8.12	0.10	1.80
95RME-0111	356568	4981874	Palmerston	litharenite, geochron site	Ompah	75.23	0.73	7.65

Sample Name	Fe$_2$O$_3$ (wt %)	FeO (wt %)	MnO (wt %)	MgO (wt %)	CaO (wt %)	Na$_2$O (wt %)	K$_2$O (wt %)	P$_2$O$_5$ (wt %)	LOI (wt %)	S (wt %)	H$_2$O+ (wt %)	CO$_2$ (wt %)
95RME-0001	4.13	0.00	0.01	0.31	0.31	3.90	4.85	<0.05	0.21	NA	NA	NA
95RME-0002	9.94	0.00	0.06	0.85	1.79	6.00	3.35	0.47	0.57	NA	NA	NA
95RME-0003	13.00	0.00	0.18	2.10	2.76	4.75	2.15	0.68	0.28	NA	NA	NA
95RME-0004	4.46	0.00	0.03	0.19	0.29	3.81	4.02	<0.05	0.34	NA	NA	NA
95RME-0005	9.29	0.00	0.21	1.78	4.85	3.87	2.84	0.52	1.68	NA	NA	NA
95RME-0096	5.80	4.77	0.19	4.74	8.31	2.85	1.64	0.18	2.56	0.01	1.05	1.93
95RME-0097	1.47	4.91	0.02	5.64	4.60	1.14	4.00	0.06	2.20	0.08	1.85	1.42
95RME-0098	0.63	1.86	0.01	1.78	3.07	3.39	3.52	0.17	3.32	0.18	1.39	2.12
95RME-0099	0.00	1.53	0.07	20.43	29.45	0.01	0.08	0.06	46.72	<0.01	0.04	44.10
95RME-0100	0.36	0.95	0.20	16.19	31.61	0.23	0.25	<0.05	40.37	0.17	0.77	38.00
95RME-0111	2.31	0.64	0.05	1.29	6.08	0.47	2.43	<0.05	3.52	<0.01	0.93	2.41

Sample Name	FeO (wt %)	Total (wt %)	Mg Number	CIA	Cr (ppm)	Ni (ppm)	Co (ppm)	Cu (ppm)	Sc (ppm)	V (ppm)	Zn (ppm)	Pb (ppm)	Mo (ppm)
95RME-0001	3.72	99.55	12.95	57.38	5	NA	NA	NA	NA	NA	NA	NA	NA
95RME-0002	8.94	98.63	14.49	57.85	10	NA	NA	NA	NA	NA	NA	NA	NA
95RME-0003	11.70	98.46	24.25	59.82	3	NA	NA	NA	NA	NA	NA	NA	NA
95RME-0004	4.01	95.41	7.78	57.33	6	NA	NA	NA	NA	NA	NA	NA	NA
95RME-0005	8.36	98.68	27.52	53.08	9	NA	NA	NA	NA	NA	NA	NA	NA
95RME-0096	9.99	99.98	45.83	55.12	114	48	29	15	28	214	109	10	<8
95RME-0097	6.23	98.59	61.73	64.84	13	31	<5	14	6	36	282	9	<8
95RME-0098	2.43	98.64	56.67	67.64	35	26	10	23	7	44	29	10	<8
95RME-0099	1.53	99.09	95.97	0.64	4	15	<5	<5	<1	21	24	<7	<8
95RME-0100	1.27	100.35	95.77	5.31	8	15	<5	5	2	21	74	105	<8
95RME-0111	2.72	100.40	45.83	46.00	24	13	5	7	6	80	29	<7	<8

Appendix 1. continued.

Sample Name	As (ppm)	W (ppm)	Cd (ppm)	Sb (ppm)	Li (ppm)	B (ppm)	Be (ppm)	Ba (ppm)	Rb (ppm)	Sr (ppm)	Nb (ppm)	Zr (ppm)	Y (ppm)	Th (ppm)
95RME-0001	NA	NA	NA	NA	NA	NA	NA	644	110	48	16	636	99	11
95RME-0002	NA	NA	NA	NA	NA	NA	NA	415	98	70	20	554	231	9
95RME-0003	NA	NA	NA	NA	NA	NA	NA	628	82	269	9	297	62	5
95RME-0004	NA	NA	NA	NA	NA	NA	NA	618	97	22	15	608	92	25
95RME-0005	NA	NA	NA	NA	NA	NA	NA	536	82	145	10	421	79	6
95RME-0096	<6	<35	NA	NA	NA	NA	<3	370	36	258	11	158	37	<10
95RME-0097	<6	<35	NA	NA	NA	NA	<3	79	111	119	3	334	34	<10
95RME-0098	29	<35	NA	NA	NA	NA	<3	279	46	158	6	126	11	<10
95RME-0099	<6	<35	NA	NA	NA	NA	<3	333	<5	66	<3	10	5	<10
95RME-0100	10	<35	NA	NA	NA	NA	<3	124	8	167	<3	33	10	<10
95RME-0111	<6	<35	NA	NA	NA	NA	<3	485	55	147	8	191	27	<10

Sample Name	La (ppm)	Ce (ppm)	Pr (ppm)	Nd (ppm)	Sm (ppm)	Eu (ppm)	Gd (ppm)	Tb (ppm)	Dy (ppm)	Ho (ppm)	Er (ppm)	Tm (ppm)	Yb (ppm)	Lu (ppm)	Total REE (ppm)
95RME-0001	30.78	106.57	10.71	44.15	10.95	1.85	10.96	1.84	11.26	2.39	7.23	1.11	7.54	1.15	248.5
95RME-0002	84.62	320.22	27.79	115.56	28.79	4.73	33.18	5.83	37.13	7.88	23.40	3.41	22.29	3.33	718.2
95RME-0003	28.44	67.68	10.28	45.72	11.45	3.72	12.39	1.96	11.26	2.27	6.12	0.81	4.99	0.72	207.8
95RME-0004	47.74	98.67	15.00	60.89	13.49	1.99	11.27	1.50	6.57	1.20	3.48	0.53	4.10	0.72	267.2
95RME-0005	24.98	59.86	9.28	42.43	11.45	3.12	13.94	2.30	14.41	3.05	8.90	1.27	8.44	1.28	204.7
95RME-0096	16.42	36.72	5.21	22.11	5.63	1.58	6.11	1.00	6.16	0.27	3.64	0.52	3.35	NA	108.7
95RME-0097	30.36	56.11	7.96	31.16	6.31	1.35	6.00	0.90	4.86	1.08	2.98	0.45	2.98	NA	152.5
95RME-0098	13.59	27.71	3.81	15.26	2.76	0.96	2.31	0.31	1.46	0.30	0.78	0.11	0.73	NA	70.1
95RME-0099	0.72	3.13	0.22	0.94	0.23	0.22	0.25	<0.05	0.24	0.06	0.15	0.02	0.15	NA	6.3
95RME-0100	5.16	9.49	1.29	5.10	1.07	0.28	1.04	0.16	0.89	0.20	0.57	0.08	0.53	NA	25.9
95RME-0111	26.79	52.06	7.34	27.64	5.53	1.13	4.84	0.77	4.46	0.89	2.63	0.39	2.66	0.40	137.5

Appendix 1. continued.

Partial Analyses

Sample Name	Easting (m)	Northing (m)	Rock Type	Formation	Al_2O_3 (wt%)	V (ppm)	Cu (ppm)	Pb (ppm)	Zn (ppm)	B (ppm)	Ba (ppm)	Sb (ppm)	Th (ppm)
91RME-0002	340844	4977650	dolomite marble	Mississagagon	0.43	9	5	<10	7	27	101	0.1	<10
91RME-0119	332460	4966990	dolomite marble	Mississagagon	3.86	14	16	18	93	136	<30	1.0	<10
91RME-0121	332424	4966300	dolomite marble	Mississagagon	0.42	11	20	10	53	21	<30	0.4	<10
91RME-0123	332338	4966172	dolomite marble	Mississagagon	0.60	7	6	<10	19	118	<30	0.3	<10
91RME-0126	332249	4965861	dolomite marble	Mississagagon	0.29	10	9	<10	13	5	<30	0.8	<10
91RME-0132	356724	4985613	dolomite marble	Mississagagon	0.60	10	7	<10	11	197	<30	0.5	<10
91RME-0115B	332343	4967195	Supergroup dolomite clast in breccia	Myer Cave	0.00	5	5	<10	5	2	<30	0.2	<10
91RME-0098	339110	4971980	dolomite marble	Myer Cave	1.93	13	10	<10	43	15	<30	6.4	<10
91RME-0105B	347623	4976780	dolomite marble	Myer Cave	2.04	240	8	38	77	29	<30	3.4	<10
91RME-0102	340900	4979890	micaceous marble	Mississagagon	7.54	22	28	<10	30	50	<30	0.1	<10
91RME-0103	339190	4979275	calcite marble	Mississagagon	1.93	9	7	<10	11	106	<30	0.1	<10
91RME-0104	345666	4977983	calcite marble	Mississagagon	0.62	8	5	<10	29	13	<30	0.3	<10
91RME-0118	332399	496699	calcite marble	Mississagagon	1.64	8	8	17	34	12	<30	0.6	<10
91RME-0120	332510	4966835	calcite marble	Mississagagon	5.13	29	7	20	115	55	<30	0.6	<10
91RME-0131	356350	4985613	calcite marble	Mississagagon	0.94	6	5	<10	15	10	<30	1.3	<10
91RME-0100	338175	4971075	calcite marble	Myer Cave	0.72	12	7	<10	9	5	350	0.2	<10
91RME-0106	344126	4974625	calcite marble	Myer Cave	0.46	128	5	<10	5	3	310	0.2	<10
91RME-0134	356939	4985596	calcite marble	Myer Cave	0.46	9	5	<10	20	5	<30	0.2	<10
91RME-0087	346179	4977688	marble conglomerate	Myer Cave	3.61	13	14	<10	21	26	<30	1.4	<10
91RME-0116	332381	4967105	fine-grained marble clast in breccia	Myer Cave	3.31	24	6	<10	28	37	<30	0.6	<10
91RME-0050	338830	4979140	litharenite	Mississagagon	15.24	57	7	<10	54	22	195	0.1	<10
91RME-0094	342250	4974250	epidote schist	Mississagagon	13.67	58	7	<10	173	82	695	1.0	<10
91RME-0105D	347623	4976780	epidote schist	Mississagagon	18.87	85	91	<10	55	85	<30	0.3	<10
91RME-0097B	339300	4972290	schist	Bishops Corners	17.46	125	5	<10	71	170	<30	0.7	<10
91RME-0105C	347623	4976780	schist	Bishops Corners	15.22	248	5	<10	48	248	<30	0.3	<10
91RME-0105A	347623	4976780	schist	Myer Cave	9.68	340	30	42	116	106	<30	4.9	<10
91RME-0108	334979	4968991	sulphide schist, unlaminated	Myer Cave	11.88	121	37	<10	91	160	<30	1.0	<10
91RME-0113	332392	4967365	sulphide schist, unlaminated	Myer Cave	5.76	118	22	<10	76	66	<30	0.6	<10
91RME-0114	332392	4967365	sulphide schist, laminated	Myer Cave	3.16	49	21	<10	22	36	<30	0.4	<10
91RME-0115A	332343	4967195	matrix to breccia	Myer Cave	1.93	38	9	<10	21	18	<30	0.3	<10
91RME-0133	357109	4985658	biotite-garnet-sillimanite schist	Myer Cave	18.89	143	13	15	132	92	<30	0.1	<10
91RME-0091	347854	4976477	mudstone	Fernleigh	11.04	80	45	16	150	104	595	0.3	<10
91RME-0092	343222	4974500	schist	Fernleigh	19.05	108	38	<10	68	162	240	0.1	<10
91RME-0093	343188	4974460	schist	Fernleigh	18.99	141	5	<10	26	227	560	0.1	<10
91RME-0101	341850	4980250	schist, scapolite	Fernleigh	12.36	55	11	<10	42	442	<30	0.1	<10
91RME-0107	341664	4973144	schist	Fernleigh	12.25	106	32	23	160	129	854	0.6	<10
91RME-0122	332424	4966270	calc-silicate dike		15.58	40	7	23	70	251	<30	4.7	<10

Appendix 2

Listing of Assay Data on Rock Units in the Study Area Collected as Part of This Study

Notes:

Detection limit for Au is 2 ppb, <5 ppm for Cu, Ni and Cr, and <10 ppm for Zn and Pb.
Background levels in area are generally close to detection limits.
All samples analyzed for Pb and Ni, only significant values are reported.
ND = not determined.
All samples analyzed by the Geoscience Laboratories, Ministry of Northern Development and Mines, Sudbury, unless otherwise indicated.

**These samples were analysed by the former Timiskaming Testing Laboratories of the Ontario Geological Survey, Cobalt. Detection limits for these samples are as follows: Au is 0.01 ounces Au per ton, <10 ppm for Cu, Ni, Zn and Pb. All samples were analyzed for Pb and Ni, but only significant values are reported.

Appendix 2. Listing of assay data on rock units in the study area collected as part of this study.

Sample Number	Easting (m)	Northing (m)	Au (ppm)	Cu (ppm)	Zn (ppm)	Other (ppm: Pt, Pd in ppb)	Comment
Flinton Group metasediments and cross-cutting sulphide veins							
91RME-0083	334979	4968991	4	33	104		Lower Myer Cave Fm., 15% bedded pyrite
91RME-0095	341812	4973499					Upper Myer Cave Formation
91RME-0096	340460	4972460					Upper Myer Cave Formation
91RME-0099	339020	4971905					Dolomite marble, pit, Hardie property
91RME-0109	342119	4973657					Upper Myer Cave Formation
91RME-0133B	357109	4985658	<2	220	<10		Myer Cave Fm., with disseminated sulphide
91RME-1002	338820	4971730	<2	33	148	Ni=26	Lower Myer Cave Formation
91RME-1004	338150	4971040	<2	75	20	Ni =95	Calcite marble with quartz boudins, Myer Cave Formation
91RME-1008	339720	4971770	<2	30	109		Lower Myer Cave Fm., 5% bedded pyrite
91RME-1012A	340460	4972460	<2	121	1400	Ni=295, Pb=73	Cross-cutting sulphide vein, Myer Cave Fm.
91RME-1012B	340460	4972460	<2	440	1600	Ni=170, Pb=76	Cross-cutting sulphide vein, Myer Cave Fm.
91RME-1012C	340460	4972460	<2	49	183	Ni =43	Lower Myer Cave Formation
91RME-1015	341812	4973499	11	167	136	Ni=187	Cross-cutting sulphide vein, Myer Cave Fm.
91RME-1024	341750	4973460	4	40	95		Myer Cave Formation.
91RME-1026	337710	4970860	18	17	19	Ni=79, Pb=19	Myer Cave Fm., pyrite nodule
91RME-1124	343730	4974280	<2	31	<10		Plagioclase-quartz-muscovite-pyrite vein, Myer Cave Formation.
91RME-1125	343760	4974445	<2	31	128		Lower Myer Cave Formation.
91RME-2146	340520	4976000	<2	11	210		Disseminated sulphide, Bishop Corners Formation pelite, Sand Lake area
91RME-2147	340680	4975990	17	875	100		Disseminated sulphide, Bishop Corners Formation pelite, Sand Lake area
92RME-0080**	349980	4985100	Nil	46	116	Ni=16	Rusty biotite-garnet-sillimanite schist, Myer Cave Formation
Gossan zones in metaplutonic rocks							
91RME-0004	334887	4986908	<2	330	26	Ni=29	Rusty quartz vein, Abinger Granite
91RME-0011	335660	4982540	<2	580	20	Ni=56	Calc-silicate xenolith in Abinger Granite
91RME-0014	335450	4983430	10	8	41		Disseminated sulphide in Abinger Granite
91RME-0017	335800	4982180	<2	64	49	Pb=275	Disseminated sulphide in Abinger Granite
91RME-0200A	327700	4972800	14	9	<10		Yellow-white gossan, Abinger Granite
91RME-0200B	327700	4972800	107	7	26		Black-white gossan, Abinger Granite
91RME-0200C	327700	4972800	13	<59	<10		Sulphides in quartz vein, Abinger Granite
91RME-2005	336850	4982270	<2	12	63		Pyrite in paragneiss xenolith, Abinger Granite
91RME-2020	336850	4981020	<2	171	6		Gossan, Abinger Granite
91RME-2025	337570	4979380	<2	30	11		Gossan, Abinger Granite
91RME-2092	335260	4978860	<2	6	<10		Sulphide in mafic xenolith in tonalite
91RME-2139	328090	4971735	<2	8	18		Pyrite, Abinger Granite
91RME-2148	326680	4984250	13	730	52		Sulphide in mafic xenolith in tonalite
Samples from older shear zones							
91RME-0031	325550	4973120	<2	10	14		Hematite-pyrite rock, Highway 41
91RME-0032	325440	4973450	<2	7	9		Highway 41
91RME-0178B	343380	4980000	200	585	110		Pyrite-pyrrhotite vein in mafic mylonite, Plevna
91RME-1104A	334130	4977700	35	51	17		Altered and sheared rock, Big Dipper Mine
91RME-1104B	334130	4977700	19	91	13		Quartz vein, dump, Big Dipper Mine
91RME-1126	341430	4978000	<2	<5	32		Mylonite derived from calc-silicates?
91RME-2060	334470	4988680	<2	43	19		Pyrite in quartz vein in sheared Abinger Granite
91RME-2104A	334000	4974830	<2	<5	92		Epidotized sheared Abinger Granite
91RME-2104B	334000	4974830	<2	12	127		Less sheared than 91RME-2104A
91RME-2112	329785	4969060	3	29	595	Pb = 194	Sheared dolomitic marble
91RME-2113	329755	4969070	13	6	39		Sheared mafic mylonite
91RME-2128	340500	4975100	<2	<5	28		Calc-silicate mylonite
91RME-2131	341030	4975390	<2	7	14		Calc-silicate mylonite
91RME-2142	330130	4971490	<2	10	49		Altered felsite, near Buffadison occurrence

Appendix 2. continued.

Sample Number	Easting (m)	Northing (m)	Au (ppm)	Cu (ppm)	Zn (ppm)	Other (ppm; Pt, Pd in ppb)	Comment
Quartz-tourmaline veins							
91RME-0097A	339300	4972290					Malachite stain, pit, Hardie property, hosted in Bishop Corners Formation meta-arenite
91RME-0143	331099	4969526	15	21	73		Discordant vein, Star of East mine
91RME-0144	331076	4969547	<2	<5	<5		Discordant vein, Star of East mine
91RME-0145	330979	4969487	225	<5	36		Quartz-actinolite vein, Star of East mine, subconcordant in chalcopyrite-bearing dolomite
91RME-0157	332200	4972975	<2	10	41		Concordant vein in felsic mylonite
91RME-0178A	343510	4979750	<2	22	166		Vein cuts mafic mylonite, Plevna
91RME-0180	338900	4975685	<2	20	49		Cuts granite-Flinton Group metaconglomerate contact, Sand Lake area
91RME-0185	341600	4975860	<2	8	36		Hosted in Flinton Group metaconglomerate, Sand Lake area
91RME-0187A	340950	4975790	<2	<5	39		Hosted in Flinton Group metaconglomerate, Sand Lake area
91RME-0187B	340950	4975790	<2	<5	47		Disseminated tourmaline in Flinton Group metaconglomerate in Sand Lake area
Metagabbroic rocks							
91RME-0060	318980	4976480	<2	32	175	Cr=970, Ni=240, V=725, Pt+ Pd=<1	Hornblendite, Bon Echo Provincial Park
91RME-0138	315199	4973605	39	26	92		Disseminated sulphide in metagabbro, southwest shore, Rainy Lake
91RME-0162	324930	4969770	15	645	57		Disseminated sulphide in metagabbro, Pringle Lake
91RME-1141	318800	4976340	49	12	155	Cr=1550, V=327, Pt=67, Pd=125	Fine-grained, magnetite-rich altered hornblendite, Bon Echo Provincial Park
Miscellaneous samples							
91RME-0038	324885	4977525	<2	7	14		Fault gouge, Abinger Granite
91RME-0044	340065	4976615	4	33	104		Hematite-chlorite marble, possible fault gouge
91RME-0124	332280	4966089	11	210	112		Hematite-malachite dolomitic marble
91RME-0170	340870	4975780	<2	12		Cr=46	Massive magnetite from old pit
91RME-0171	340900	4975880	<2	27	159		Tourmaline-bearing skarn rock, Sand Lake area
91RME-0177	343430	4980100	4	23	90		Pyrite-chalcopyrite-sphalerite? in calcite marble, construction pit, Plevna schoolyard
91RME-0232	338315	4974800	Nil	23	<10		Northwest-trending fault in Norway Lake granite
91RME-1006A	338580	4971330	<2	43	31		Dolomite marble, possible fault zone
91RME-1006b	338580	4971330	<2	43	190		Fault gouge derived from dolomite marble
91RME-1085	338940	4973870	<2	9	21		Hematite-chloritized marble from construction pit, north-northwest trending fault zone
91RME-1086	340720	4978390	6	23	180		Gossan zone in metawacke
91RME-1119A	340640	4976760	<2	12	47		Calc-silicate
91RME-1119B	340640	4976760	<2	9	99		Hematite-chloritized marble
91RME-2026	337570	4979350	4	82	455	Pb=21	Disseminated sulphide in mafic metawacke
91RME-2133	340870	4979350	<2	22	245		Garnet-epidote skarn rock, Sand Lake area
92RME-0057**	352280	4984200	Nil	6	22	Ni=24	Impure marble with pyrite, pyrrhotite
92RME-0314A	356000	4990260	10	59	27	Ni=75, Pb<10	Rusty, pyrrhotite-bearing schist
92RME-0314B	356000	4990260	9	40		Ni=75, Pb<10	Rusty, pyrrhotite-bearing schist
92RME-1025A**	361450	4985315	Nil	56	70	Ni=27	Rusty schist
92RME-1025B**	361450	4985315	Nil	39	11	Ni=18	Quartz vein
92RME-1028**	361475	4984990	Nil	267	11	Ni=15	Rusty schist
92RME-1054**	361780	4987810	Nil	419	22	Ni=82, Pb=40	Gossan zone in mafic metawacke
92RME-1056**	361275	4987990	trace	59	38	Pb=26	Vein in granite
92RME-1056**	361275	4987990	trace	59	38	Pb=26	Vein in granite
92RME-2010	354000	4986180	Trace	59	14		Sulphide in marble
93RME-0012	333639	4966376		26		<0.01 oz/ton Au	Helena stock

Appendix 2. continued.

Sample Number	Easting (m)	Northing (m)	Au (ppm)	Cu (ppm)	Zn (ppm)	Other (ppm, Pt, Pd = ppb)	Comment
Samples from host rocks at the Summit Lake Iron Mine							
92RME-0315	354820	4990150	3	7			Garnet-pyroxenite
92RME-0316	354820	4990150	<3	<5			Felsic gneiss (metaplutonic)
92RME-0317	354820	4990150	<3	11			Mafic gneiss on strike with ore zone
92RME-0318	354820	4990150	<3	11			Felsic gneiss (intrusion breccia?)
92RME-0319	354820	4990150	<3	13			Felsic gneiss (intrusion breccia?)
92RME-0320	354820	4990150	3	<5			Quartz vein cutting marble breccia
Samples near the Summit Lake Iron Mine							
92RME-0321	355250	4990350	<3	61			Rusty amphibolite pod in calcite marble
92RME-0322	355250	4990300	<3	8			Rusty late tonalite vein
92RME-0323	355240	4990260	<3	19			Quartz vein cutting rusty amphibolite
92RME-0324	355210	4990225	<3	39			Leucosome-rich gneissic metawacke
92RME-0325	355240	4990220	66	109			Rusty amphibolite (pillowed?)

Metric Conversion Table

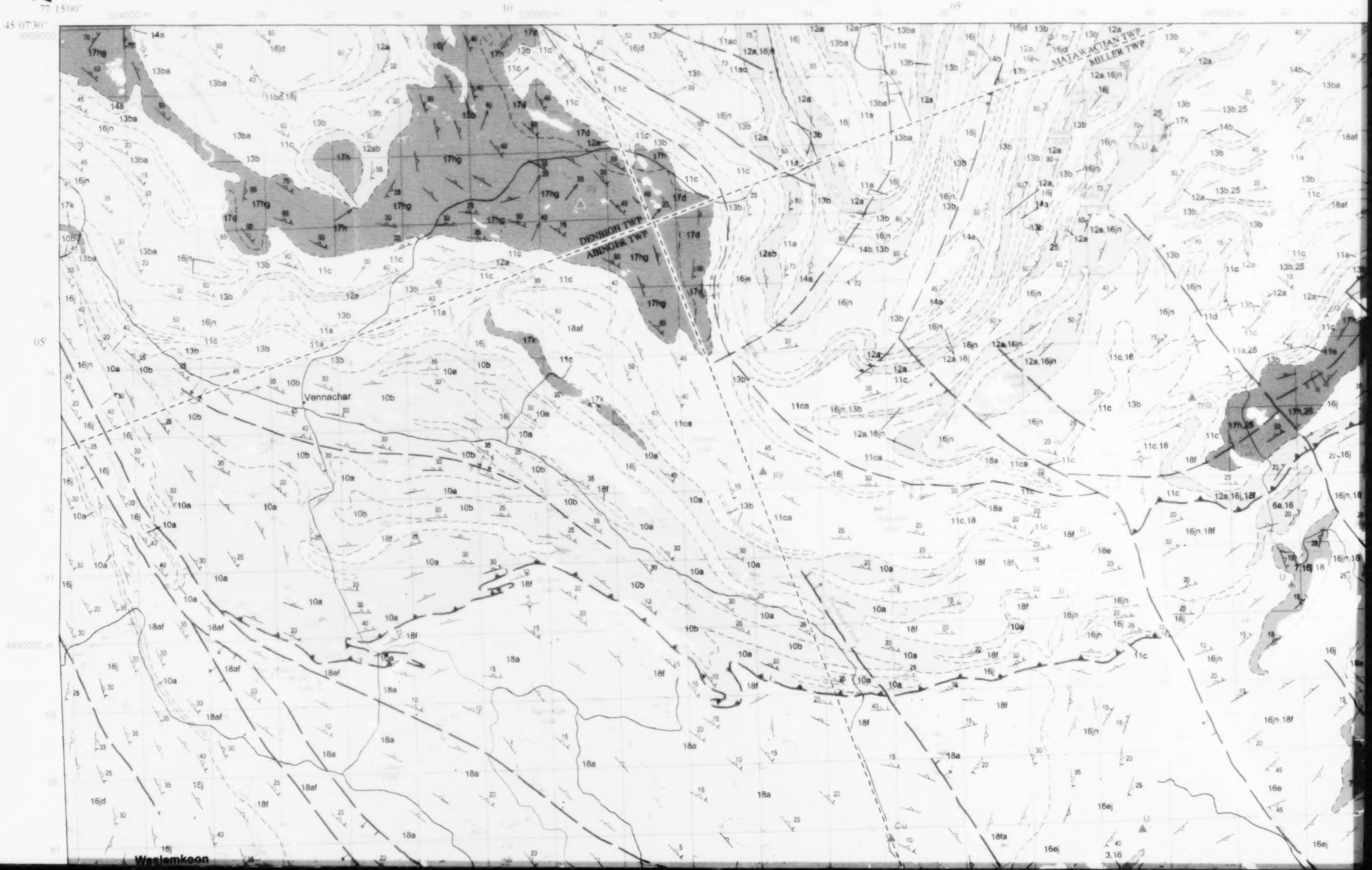
Conversion from SI to Imperial			Conversion from Imperial to SI		
SI Unit	*Multiplied by*	*Gives*	*Imperial Unit*	*Multiplied by*	*Gives*
			LENGTH		
1 mm	0.039 37	inches	1 inch	**25.4**	mm
1 cm	0.393 70	inches	1 inch	**2.54**	cm
1 m	3.280 84	feet	1 foot	**0.304 8**	m
1 m	0.049 709	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	**1.609 344**	km
			AREA		
1 cm^2	0.155 0	square inches	1 square inch	**6.451 6**	cm^2
1 m^2	10.763 9	square feet	1 square foot	**0.092 903 04**	m^2
1 km^2	0.386 10	square miles	1 square mile	2.589 988	km^2
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
			VOLUME		
1 cm^3	0.061 023	cubic inches	1 cubic inch	**16.387 064**	cm^3
1 m^3	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m^3
1 m^3	1.307 951	cubic yards	1 cubic yard	0.764 554 86	m^3
			CAPACITY		
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	**4.546 090**	L
			MASS		
1 g	0.035 273 962	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 747	ounces (troy)	1 ounce (troy)	**31.103 476 8**	g
1 kg	2.204 622 6	pounds (avdp)	1 pound (avdp)	**0.453 592 37**	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	**907.184 74**	kg
1 t	1.102 311 3	tons (short)	1 ton (short)	**0.907 184 74**	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	**1016.046 908 8**	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	**1.016 046 90**	t
			CONCENTRATION		
1 g/t	0.029 166 6	ounce (troy)/ ton (short)	1 ounce (troy)/ ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights/ ton (short)	1 pennyweight/ ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

	Multiplied by	
1 ounce (troy) per ton (short)	31.103 477	grams per ton (short)
1 gram per ton (short)	0.032 151	ounces (troy) per ton (short)
1 ounce (troy) per ton (short)	20.0	pennyweights per ton (short)
1 pennyweight per ton (short)	0.05	ounces (troy) per ton (short)

Note: Conversion factors which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries, published by the Mining Association of Canada in co-operation with the Coal Association of Canada.

Southern part of Bancroft terrane - Black Donald domain



77°15'00"
10'
05'
45°07'30"
4999000
330000 m
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DENBIGH TWP
ABINGER TWP
MATAWATCHAN TWP
MILLER TWP
Vennachar
Weslemkoon
py
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Cu
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17d
17h
17k
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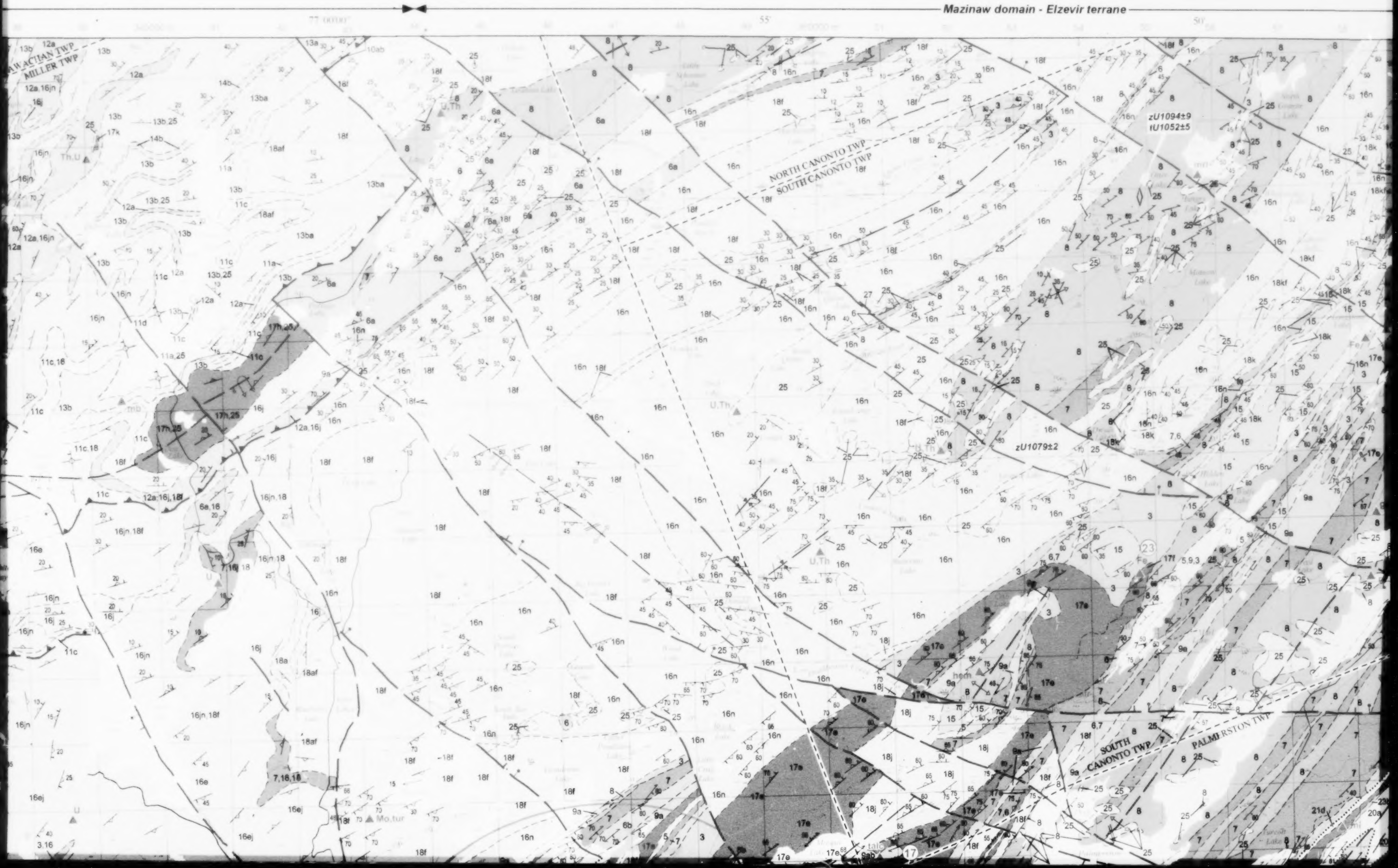 Mazinaw domain - Elzevir terrane
77°00'00"
55'
50'
MILLER TWP
NORTH CANONTO TWP
SOUTH CANONTO TWP
SOUTH CANONTO TWP
PALMERSTON TWP
zU1094±9
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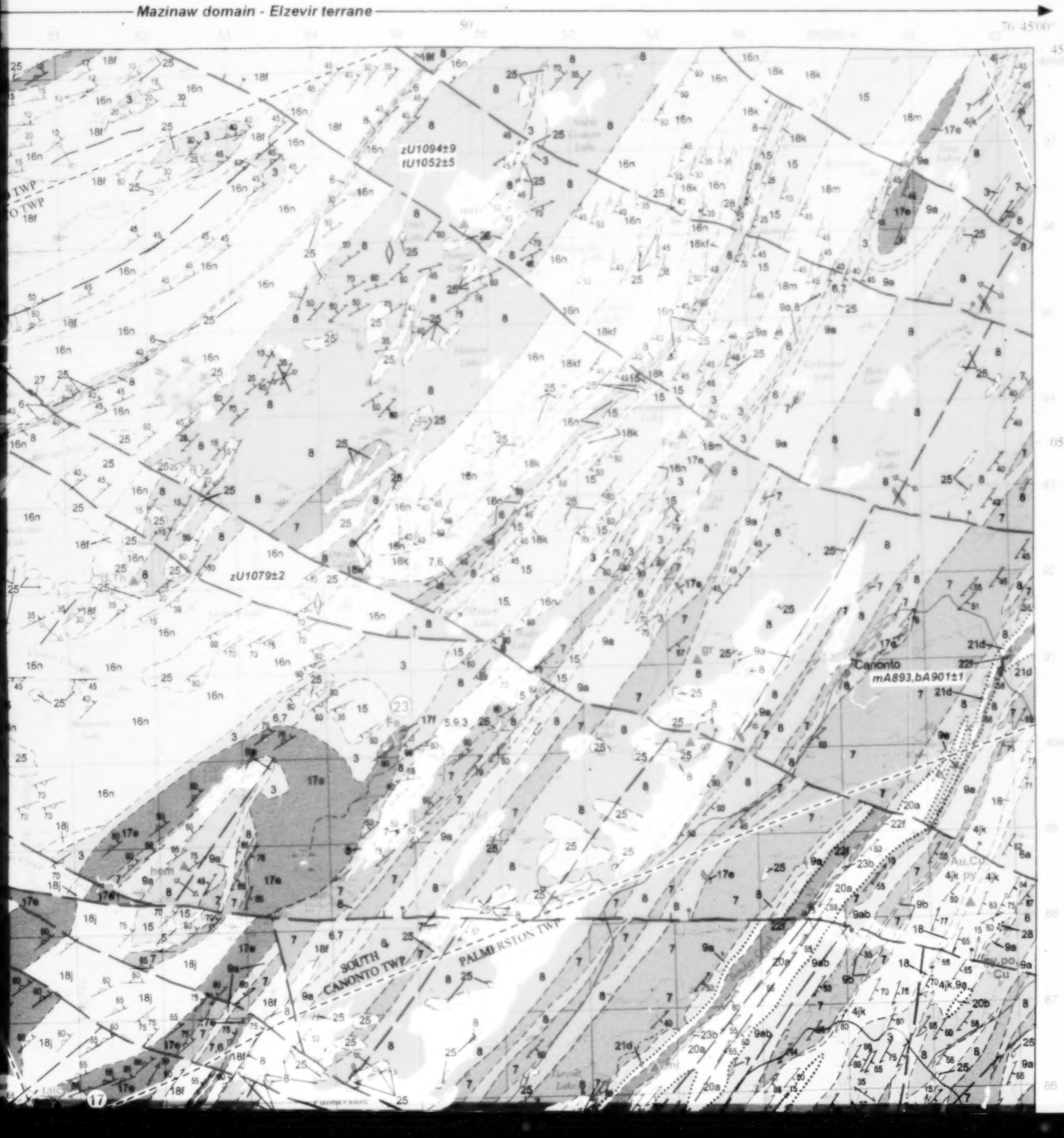

LEGEND

PHANEROZOIC

CENOZOIC

QUATERNARY

PLEISTOCENE AND RECENT

Sand, gravel, mainly glaciofluvial deposits, till, ground moraines, and organic deposits

UNCONFORMITY

PALEOZOIC

MIDDLE ORDOVICIAN

Gull River Formation

28 **Chemical Sedimentary Rocks**
Pale grey and brown, sublithographic to lithographic limestone, minor dolostone

UNCONFORMITY

PRECAMBRIAN[ab]

NEOPROTEROZOIC

27 / **Grenville Dike Swarm (590 Ma)**
Fine- to medium-grained diabase

INTRUSIVE CONTACT

MESOPROTEROZOIC

LATE TECTONIC TO POSTTECTONIC INTRUSIVE ROCKS

26 / **Mafic Intrusive Rocks (<1080 Ma)**
Fine-grained, weakly metamorphosed, diabase and basaltic dikes

INTRUSIVE CONTACT

25 **Potassic Pegmatitic Intrusive Rocks (1020 to 1170 Ma)**
Pink-weathering, syenite to syenogranite pegmatite veins, locally may contain tourmaline or muscovite or both

INTRUSIVE CONTACT

24 **Felsic Intrusive Rocks (Kensington–Skootamatta Intrusive Suite[c]) (1050 to 1075 Ma)**
Biotite syenite, medium- to coarse-grained, pink to red, biotite syenite, ± clinopyroxene ± hornblende

INTRUSIVE CONTACT

Greenschist to Lower Amphibolite Facies Metamorphism in
Grimsthorpe Domain at ~1080 Ma
Greenschist to Upper Amphibolite Facies in
Mazinaw Domain at ~1080 Ma and ~1030 Ma

Metasedimentary Rocks of the Flinton Group
(>1020 Ma, <1155 Ma)

23 **Fernleigh Formation**
23a Biotite-diopside-carbonate-hornblende schist
23b Biotite-diopside-carbonate-hornblende schist and high-grade equivalents

Myer Cave Formation

13 **Calcitic Carbonate**
13a Calcite marb
and massive,
boudinaged l
metasedimen
13b Calcite marb
and massive,
impurities, co
of unit 12

12 **Siliceous Clastic M**
12a Biotite quartz
35% biotite, m
metapelite an
horizons
12b Rusty schist

11 **Siliceous Clastic M**
Felsic and Interme
Rocks of Mainly V
11a Biotite-hornbl
("para-amphi
gneiss, with l
locally
11b Biotite-hornbl
("para-amphi
and quartzofe
bearing
11c Unit 11a, inte
11d Unit 11a, inte

Metavolcanic Rocks

10 **Mafic Metavolcani**
10a Basalt flows;
thin felsic me
composition
10b Biotite amphi
andesite and
breccias and
calc-alkalic in
equivalents?)

FAULT

MAZINAW D

GRENVILLE SUPE

Metasedimentary Rocks

9 **Dolomitic Carbon**
9a Dolomite ma
and massive,
assemblages
9b Unit 9a, inter
metasedimen

8 **Calcitic Carbonat**
8a Calcite marb
and massive,
marble, main
layers of silic
(unit 6 and 7)
8b Marble, interl

7 **Siliceous Clastic**
Biotite quartzofelds
biotite, mainly deriv
and rusty schist, mi

6 **Siliceous Clastic**
Felsic and Interme
Rocks of Mainly V
6a Biotite-hornb

LEGEND

ANEROZOIC

ENOZOIC

QUATERNARY

PLEISTOCENE AND RECENT

Sand, gravel, mainly glaciofluvial deposits, till, ground moraines, and organic deposits

UNCONFORMITY

ALEOZOIC

MIDDLE ORDOVICIAN

Gull River Formation

Chemical Sedimentary Rocks
Pale grey and brown, sublithographic to lithographic limestone, minor dolostone

UNCONFORMITY

CAMBRIAN[ab]

EOPROTEROZOIC

Grenville Dike Swarm (590 Ma)
Fine- to medium-grained diabase

INTRUSIVE CONTACT

ESOPROTEROZOIC

TECTONIC TO POSTTECTONIC INTRUSIVE ROCKS

Mafic Intrusive Rocks (<1080 Ma)
Fine-grained, weakly metamorphosed, diabase and basaltic dikes

INTRUSIVE CONTACT

Potassic Pegmatitic Intrusive Rocks (1020 to 1170 Ma)
Pink-weathering, syenite to syenogranite pegmatite veins, locally may contain tourmaline or muscovite or both

INTRUSIVE CONTACT

Felsic Intrusive Rocks (Kensington–Skootamatta Intrusive Suite[c]) (1050 to 1075 Ma)
Biotite syenite, medium- to coarse-grained, pink to red, biotite syenite, ± clinopyroxene ± hornblende

INTRUSIVE CONTACT

enschist to Lower Amphibolite Facies Metamorphism in Grimsthorpe Domain at ~1080 Ma
Greenschist to Upper Amphibolite Facies in Mazinaw Domain at ~1080 Ma and ~1030 Ma

Metasedimentary Rocks of the Flinton Group (>1020 Ma, <1155 Ma)

Fernleigh Formation
23a Biotite-diopside-carbonate-hornblende schist
23b Biotite-diopside-carbonate-hornblende schist and high-grade equivalents

13 **Calcitic Carbonate Metasedimentary Rocks**
13a Calcite marble, generally medium to coarse grained and massive, main include zones with intact or boudinaged layers of siliceous clastic metasedimentary rocks (unit 11 and 12)
13b Calcite marble, generally medium to coarse grained and massive, containing 20 to 60% siliceous impurities, commonly contains thin intercalated layers of unit 12

12 **Siliceous Clastic Metasedimentary Rocks**
12a Biotite quartzofeldspathic gneiss, fine grained, 10 to 35% biotite, mainly derived from metawacke, minor metapelite and rusty schist, minor metaquartzarenite horizons
12b Rusty schist

11 **Siliceous Clastic Metasedimentary Rocks, may include Felsic and Intermediate Metatuffs and Metasedimentary Rocks of Mainly Volcanic Provenance**
11a Biotite-hornblende-quartz-plagioclase gneiss ("para-amphibolite") and hornblende-plagioclase gneiss, with layers of unit 10a and/or 10b present locally
11b Biotite-hornblende-quartz-plagioclase gneiss ("para-amphibolite"), hornblende-plagioclase gneiss, and quartzofeldspathic gneiss, commonly garnet bearing
11c Unit 11a, interlayered with rocks of unit 12a
11d Unit 11a, interlayered with rocks of unit 12b

Metavolcanic Rocks

10 **Mafic Metavolcanic Rocks**
10a Basalt flows, locally containing pillows, breccias and thin felsic metavolcanic units, mainly tholeiitic in composition (Tudor Formation equivalents?)
10b Biotite amphibolite and minor amphibolite derived from andesite and basalt flows, locally contains pillows, breccias and thin felsic metavolcanic units, possibly calc-alkalic in composition (Kashwakamak Formation equivalents?)

FAULTED CONTACT

MAZINAW DOMAIN (units 3 to 9)

GRENVILLE SUPERGROUP

Metasedimentary Rocks

9 **Dolomitic Carbonate Metasedimentary Rocks**
9a Dolomite marble, generally medium to coarse grained and massive, may include zones of calc-silicate assemblages (e.g., tremolite, diopside)
9b Unit 9a, interlayered with siliceous clastic metasedimentary rocks (unit 7)

8 **Calcitic Carbonate Metasedimentary Rocks**
8a Calcite marble, generally medium to coarse grained and massive, locally layered, medium-grained calcite marble, main include zones with intact or boudinaged layers of siliceous clastic metasedimentary rocks (unit 6 and 7)
8b Marble, interlayered with unit 6d

7 **Siliceous Clastic Metasedimentary Rocks**
Biotite quartzofeldspathic gneiss, fine-grained, 10 to 35% biotite, mainly derived from metawacke, minor metapelite and rusty schist, minor metaquartzarenite horizons

6 **Siliceous Clastic Metasedimentary Rocks, may include Felsic and Intermediate Metatuffs and Metasedimentary Rocks of Mainly Volcanic Provenance**

SYMBOLS

- Geological contact (interpreted)
- Unconformity (trend only, interpreted)
- Fault (interpreted)
- Fault; downthrown, magnitude of vertical displacement unknown, unknown horizontal displacement (inclined, down-dropped side indicated, interpreted)
- Fault; thrust fault, approximates southern limit of Black Donald domain (trend only, hanging-wall side indicated, interpreted)
- Fold; anticline, first generation (trend only, limbs dip in opposite direction, interpreted)
- Fold; anticline, second generation (trend only, limbs dip in opposite direction, interpreted)
- Fold; antiform, unknown generation (trend only, limbs dip in opposite direction, interpreted)
- Fold; antiform, second generation (trend only, limbs dip in opposite direction, interpreted)
- Fold; antiform, second generation (trend only, limbs dip in same direction, interpreted)
- Fold; synform, first generation (trend only, limbs dip in opposite direction, interpreted)
- Fold; synform, second generation (trend only, limbs dip in opposite direction, interpreted)
- Fold; synform, second generation (trend only, limbs dip in same direction, interpreted)
- 30 Bedding; sedimentary, facing unknown (inclined, vertical)
- 30 Bedding; sedimentary, cross-bedded with facing known (overturned)
- 30 Bedding; sedimentary, facing known (overturned)
- Pillows, facing not known (trend only)
- Pillows, facing known (trend only)
- 30 Compositional layering and/or parallel tectonic foliation; unknown generation (trend only, horizontal, inclined, vertical)
- 30 Foliation; unknown generation (trend only, inclined, vertical)
- 30 Foliation; second generation (inclined)
- 30 Igneous layering, facing unknown (inclined)
- 30 Lineation (with plunge, without plunge)
- Isograd (text on high-grade side); diopside-in or muscovite-in; feldspar disorder indicating temperatures >500°C; hornblende-in; kyanite-in; kyanite-out; muscovite-out; scapolite+diopside-in; sillimanite-in; staurolite-out
- Approximate limit of volcanic eruptive centre
- ▲ Mineral occurrence (number corresponds with "Properties and Occurrences" list)
- 3 Property or occurence
- zU1246±3 Geochronology sample site, with age in Ma
- ◆ MA114 Location of modern alluvium sample; sample number preface 03JR- (from Felix, Reid and Easton 2006)

Ontario

Ontario Geological Survey

MAP P.3443

PRECAMBRIAN GEOLOGY

CLOYNE–PLEVNA–OMPAH AREA

Scale 1:50 000

1000 m 0 1 2 km

NTS References: parts of 31C/14, 15, 31F/2, 3

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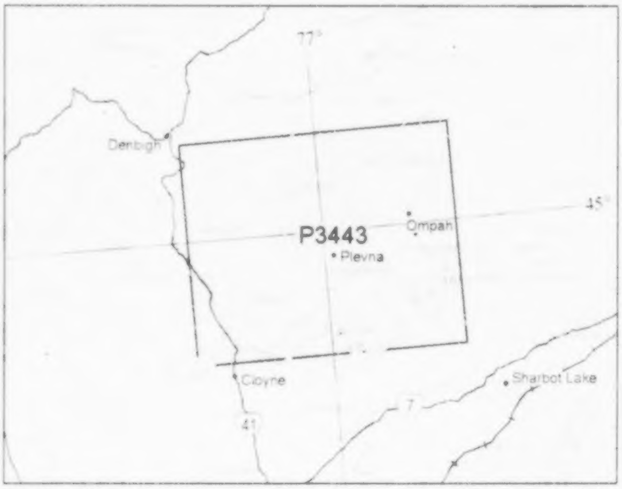


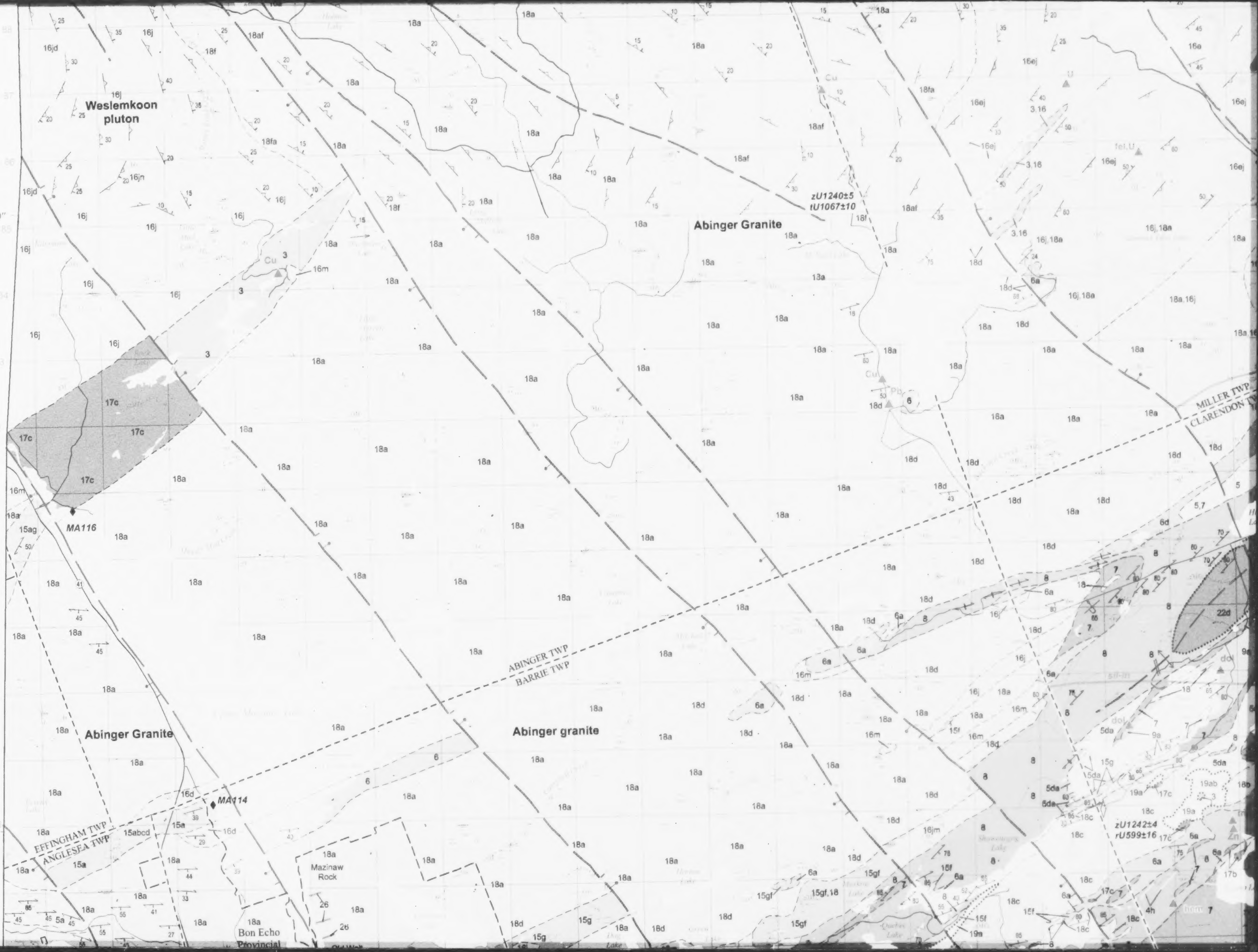
Location Map 1 cm equals 10 km

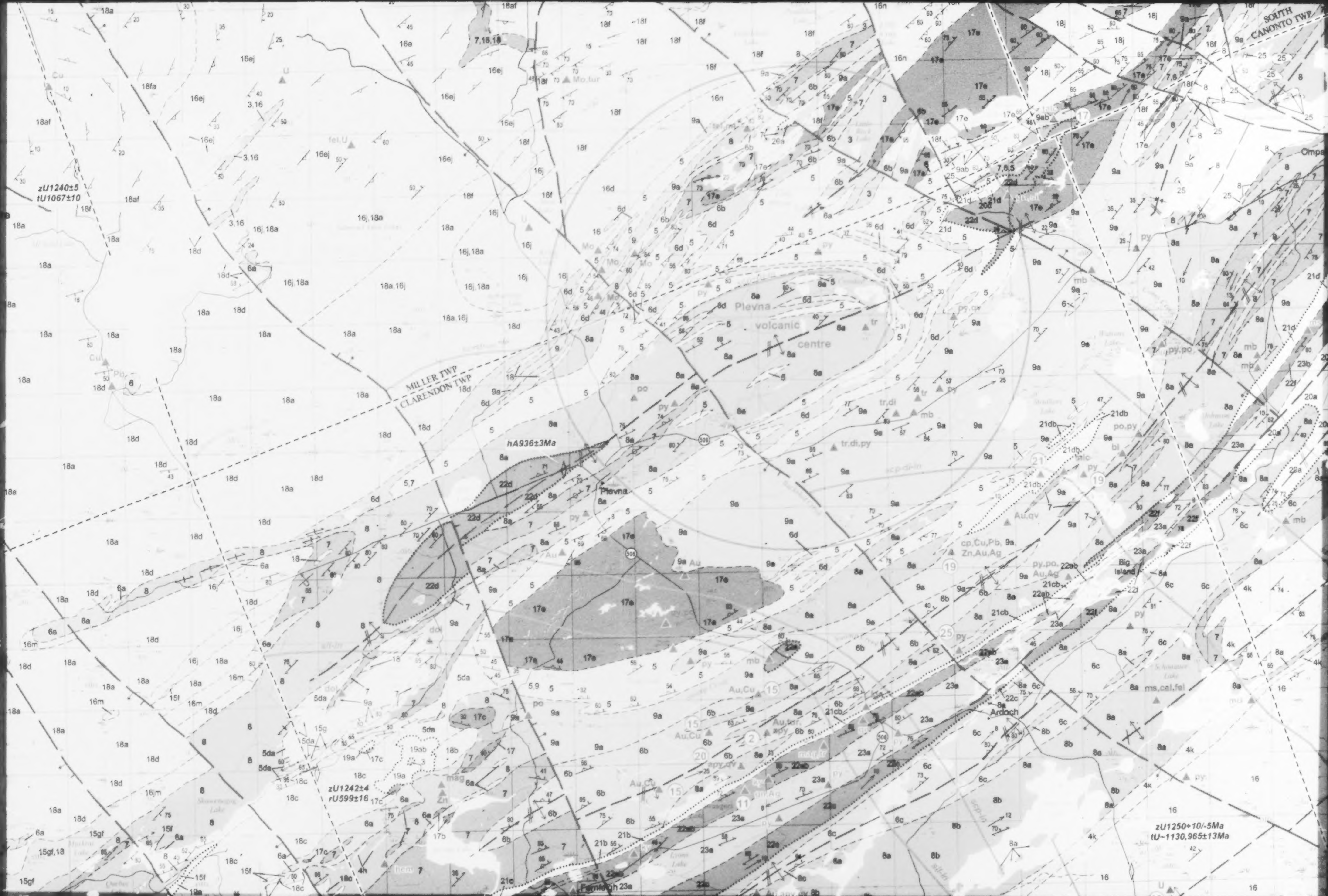
SOURCES OF INFORMATION

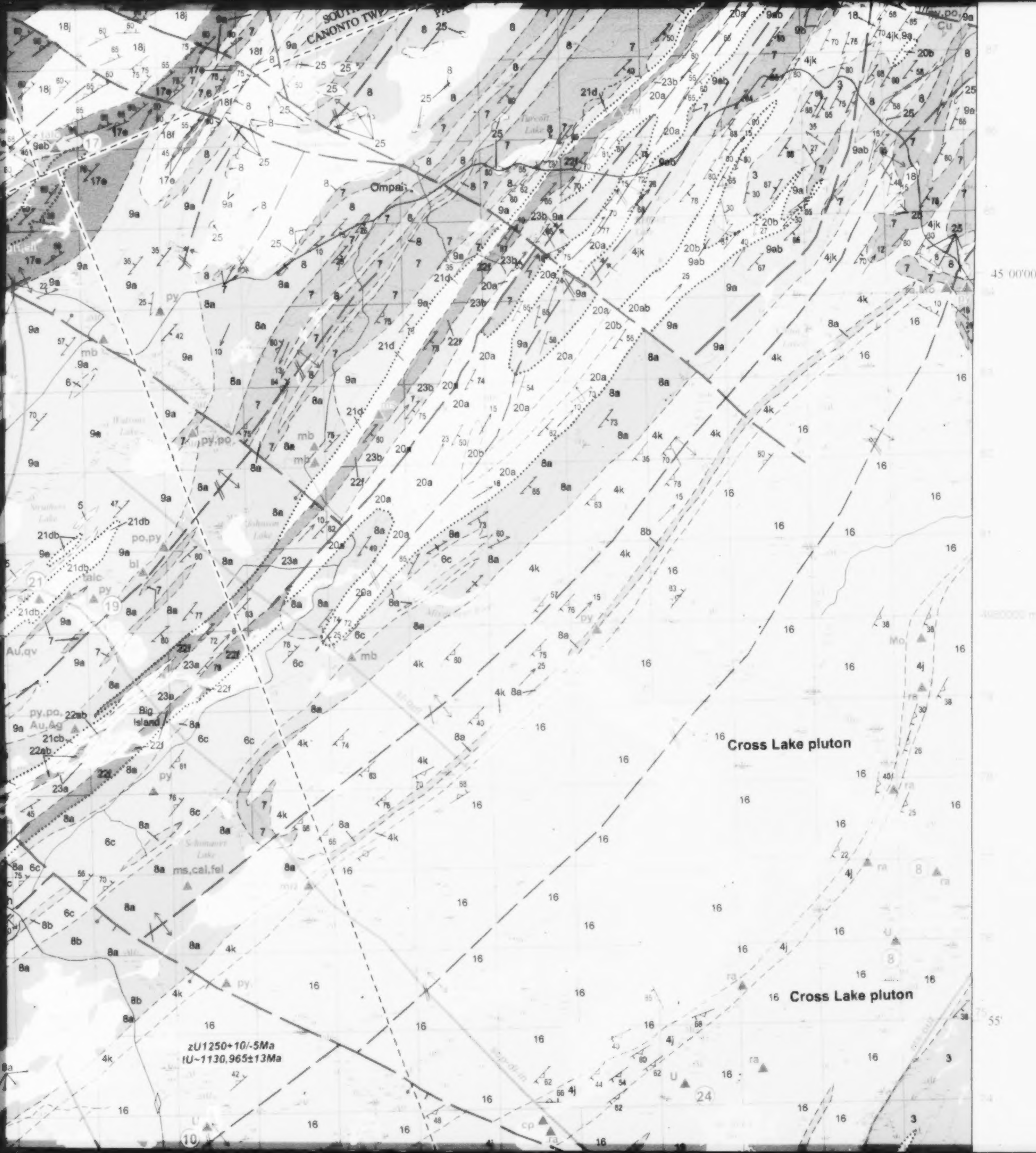
Thematic information on this map is tied to a digital base map derived from maps 31C/14, 31C/15, 31F/2 and 31F/3 of the National Topographic System, scale 1:50 000.

Mapping conducted using UTM co-ordinates in North American Datum 1927 (NAD27), Zone 18.

Ayer, J.A. 1979. Mazinaw Lake metavolcanic complex, Grenville Province; unpublished MSc thesis, Carleton University, Ottawa, Ontario.


Weslemkoon pluton
Abinger Granite
Abinger Granite
Abinger granite
zU1240±5
tU1067±10
zU1242±4
rU599±16
MA116
MA114
ABINGER TWP
BARRIE TWP
EFFINGHAM TWP
ANGLESEA TWP
MILLER TWP
CLARENDON TWP
Mazinaw Rock
Bon Echo Provincial
45 00'00"
55'
4980000 m
18a
18d
16j
17c
22d
Cu
Pb
U
dol


MILLER TWP
CLARENDON TWP
SOUTH CANONTO TWP
Plevna volcanic centre
Plevna
Ardoch
Fernleigh
Big Island
Ompa
zU1240±5
tU1067±10
hA936±3Ma
zU1242±4
rU599±16
zU1250+10/-5Ma
tU~1130,965±13Ma
cp,Cu,Pb, Zn,Au,Ag
py,po, Au,Ag
Au,Cu
Au,qv
tr,di,py
ms,cal,fel
Mo,tur
fel,U
506



Metasedimentary Rocks of the Flinton Group (>1020 Ma, <1155 Ma)

23 **Fernleigh Formation**

- 23a Biotite-diopside-carbonate-hornblende schist
- 23b Biotite-diopside-carbonate-hornblende schist and high-grade equivalents

22 **Myer Cave Formation**

- 22a Black or rusty weathering, graphite-pyrite-biotite-schist
- 22b Calcite marble, minor dolomite marble, with minor interlayered biotite schist (unit 22a)
- 22c Carbonate clast breccia, consisting of clasts of units 21b, 8 and 9, in a graphite-biotite-schist matrix
- 22d Scapolite-bearing metawacke and semi-pelitic schist
- 22e Carbonate clast metaconglomerate, calcite marble
- 22f Higher grade equivalents of unit 22a, commonly garnet and sillimanite bearing

21 **Bishop Corners Formation**

- 21a Metaconglomerate, dominated by clasts of metaquartzarenite
- 21b Metaquartzarenite
- 21c Metapelite
- 21d Muscovite-rich metapelite, minor muscovite-bearing meta-arenite

20 **Ompah Formation**

- 20a Proximally derived, heterolithic metaconglomerate, consisting of granite cobbles (unit 18) in a carbonate-diopside-mica matrix
- 20b Meta-arenite, calcareous meta-arenite
- 20c Hornblende + garnet pelitic to semi-pelitic gneiss and schist (possibly equivalent to Ore Chimney Formation)

19 **Norway Lake Formation**

- 19a Proximally derived, heterolithic metaconglomerate, locally contains clasts and boulders of unit 18c
- 19b Meta-arenite, calcareous meta-arenite

UNCONFORMITY

Methuen Suite[c] (1240 to 1250 Ma)

18 **Felsic Intrusive Rocks**

- 18a Medium-grained, pink-weathering monzogranite, massive to foliated
- 18b Fine-grained, pink-weathering monzogranite, foliated, may include deformed equivalents of unit 8
- 18c Medium-grained, pink-weathering monzogranite, massive to foliated, commonly fluorite bearing
- 18d Unit 18a, but with rafts and screens of unit 15 and/or 9 and 10
- 18e Unit 18b, sheared to mylonitic
- 18f Medium-grained, gneissic to migmatitic monzogranite, commonly cut by granite pegmatite veins (unit 25)
- 18j Medium-grained, gneissic granodiorite to quartz diorite
- 18k Fine- to medium-grained granitoid gneiss
- 18m Medium-grained, potassium feldspar megacrystic monzogranite, locally grades into augen gneiss

INTRUSIVE CONTACT

Lavant Suite[c] (1240 to 1250 Ma)

17 **Mafic to Intermediate Intrusive Rocks**

- 17a Fine- to medium-grained gabbro
- 17b Unit 17a, foliated to gneissic
- 17c Medium-grained, foliated to gneissic, gabbro, anorthositic gabbro, gabbroic anorthosite
- 17d Fine- to medium-grained tonalite and granodiorite
- 17e Medium- to coarse-grained gabbro, foliated to gneissic
- 17f Grossular-diopside skarn rock
- 17g Unit 17a, gneissic
- 17h Unit 17a, foliated to gneissic, locally preserving relict igneous texture
- 17k Gneissic gabbro and diorite sills and dikes of unknown age and affinity, may include rocks related to units 10 and 17

Elzevir Suite[c] (1250 to 1270 Ma)

- 8b Marble, inter

7 **Siliceous Clastic**

Biotite quartzofelds
biotite, mainly deriv
and rusty schist, mi

6 **Siliceous Clastic**
Felsic and Interme
Rocks of Mainly V

- 6a Biotite-hornb ("para-amphi gneiss, with
- 6b Thinly layere quartzofelds altered mylo
- 6c Calcareous, carbonate-di ("para-amphi carbonate-sc
- 6d Biotite-hornb ("para-amphi and quartzof bearing, may
- 6e Biotite-hornb derived from

UNKNO

Metavolcanic Rocks

5 **Tholeiitic Mafic to**
Lake Formation a

- 5a Felsites, pro pyroclastic r equivalents
- 5b Fine-grained biotite-hornb derived from tuffs
- 5c Fine-grained rocks, likely flows
- 5d Unit 5a, fine to dark gree gneiss, unit

4 **Calc-Alkalic Mafic**
(Kashwakamak Fo
(1265 to 1280 Ma)

- 4a Felsic tuffs
- 4b Felsic flows,
- 4f Andesite bre
- 4g Mainly flows,
- 4h Feldspar por
- 4j Dominantly biotite-bearin flows and tu
- 4k Dominantly derived from

3 **Tholeiitic Mafic M**
and equivalents)

Fine-grained, gree
garnet amphibolite
basaltic flows and
breccias, hyalocla
Also includes mafic
chemical or stratig

UNKNO

GRIMSTHORPE

2 **Mafic Intrusive Ro**

Fine- to medium-gr
gabbro, locally fol

INTRUS

CANIFF COMPLE

1 **Tholeiitic Mafic a**

Metasedimentary Rocks of the Flinton Group (>1020 Ma, <1155 Ma)

3 **Fernleigh Formation**
23a Biotite-diopside-carbonate-hornblende schist
23b Biotite-diopside-carbonate-hornblende schist and high-grade equivalents

2 **Myer Cave Formation**
22a Black or rusty weathering, graphite-pyrite-biotite-schist
22b Calcite marble, minor dolomite marble, with minor interlayered biotite schist (unit 22a)
22c Carbonate clast breccia, consisting of clasts of units 21b, 8 and 9, in a graphite-biotite-schist matrix
22d Scapolite-bearing metawacke and semi-pelitic schist
22e Carbonate clast metaconglomerate, calcite marble
22f Higher grade equivalents of unit 22a, commonly garnet and sillimanite bearing

21 **Bishop Corners Formation**
21a Metaconglomerate, dominated by clasts of metaquartzarenite
21b Metaquartzarenite
21c Metapelite
21d Muscovite-rich metapelite, minor muscovite-bearing meta-arenite

20 **Ompah Formation**
20a Proximally derived, heterolithic metaconglomerate, consisting of granite cobbles (unit 18) in a carbonate-diopside-mica matrix
20b Meta-arenite, calcareous meta-arenite
20c Hornblende + garnet pelitic to semi-pelitic gneiss and schist (possibly equivalent to Ore Chimney Formation)

19 **Norway Lake Formation**
19a Proximally derived, heterolithic metaconglomerate, locally contains clasts and boulders of unit 18c
19b Meta-arenite, calcareous meta-arenite

UNCONFORMITY

Methuen Suite[c] (1240 to 1250 Ma)

8 **Felsic Intrusive Rocks**
18a Medium-grained, pink-weathering monzogranite, massive to foliated
18b Fine-grained, pink-weathering monzogranite, foliated, may include deformed equivalents of unit 8
18c Medium-grained, pink-weathering monzogranite, massive to foliated, commonly fluorite bearing
18d Unit 18a, but with rafts and screens of unit 15 and/or 9 and 10
18e Unit 18b, sheared to mylonitic
18f Medium-grained, gneissic to migmatitic monzogranite, commonly cut by granite pegmatite veins (unit 25)
18j Medium-grained, gneissic granodiorite to quartz diorite
18k Fine- to medium-grained granitoid gneiss
18m Medium-grained, potassium feldspar megacrystic monzogranite, locally grades into augen gneiss

INTRUSIVE CONTACT

Lavant Suite[c] (1240 to 1250 Ma)

7 **Mafic to Intermediate Intrusive Rocks**
17a Fine- to medium-grained gabbro
17b Unit 17a, foliated to gneissic
17c Medium-grained, foliated to gneissic, gabbro, anorthositic gabbro, gabbroic anorthosite
17d Fine- to medium-grained tonalite and granodiorite
17e Medium- to coarse-grained gabbro, foliated to gneissic
17f Grossular-diopside skarn rock
17g Unit 17a, gneissic
17h Unit 17a, foliated to gneissic, locally preserving relict igneous texture
17k Gneissic gabbro and diorite sills and dikes of unknown age and affinity, may include rocks related to units 10 and 17

Elzevir Suite[c] (1250 to 1270 Ma)

8b Marble, interlayered with unit 6d

7 **Siliceous Clastic Metasedimentary Rocks**
Biotite quartzofeldspathic gneiss, fine-grained, 10 to 35% biotite, mainly derived from metawacke, minor metapelite and rusty schist, minor metaquartzarenite horizons

6 **Siliceous Clastic Metasedimentary Rocks, may include Felsic and Intermediate Metatuffs and Metasedimentary Rocks of Mainly Volcanic Provenance**
6a Biotite-hornblende-quartz-plagioclase gneiss ("para-amphibolite") and hornblende-plagioclase gneiss, with layers of unit 4 or 5 present locally
6b Thinly layered, fine-grained, silicified quartzofeldspathic gneisses, possibly representing altered mylonitized sedimentary rocks
6c Calcareous, flattened and sheared biotite-hornblende-carbonate-diopside gneiss and schist ("para-amphibolite"), biotite-plagioclase-quartz and carbonate-scapolite-quartz gneiss
6d Biotite-hornblende-quartz-plagioclase gneiss ("para-amphibolite"), hornblende-plagioclase gneiss, and quartzofeldspathic gneiss, commonly garnet bearing, may include layers of unit 3 or 5
6e Biotite-hornblende-quartz-plagioclase schist to gneiss, derived from volcanic wackes and volcanic arenite

UNKNOWN CONTACT

Metavolcanic Rocks

5 **Tholeiitic Mafic to Felsic Metavolcanic Rocks (Mazinaw Lake Formation and equivalents) (1240 to 1250 Ma)**
5a Felsites, probably derived from felsic tuffs and pyroclastic rocks, may include some fine-grained equivalents of unit 18
5b Fine-grained, grey to dark-grey weathering magnetite-biotite-hornblende-quartz-plagioclase gneiss, probably derived from icelandite (tholeiitic andesite) flows and tuffs
5c Fine-grained, pink to buff weathering felsic fragmental rocks, likely derived from ash-flow tuffs and pyroclastic flows
5d Unit 5a, finely intercalated with finely laminated, green to dark green, biotite-hornblende-plagioclase mafic gneiss, unit may, in part, be mylonitic in origin

4 **Calc-Alkalic Mafic to Felsic Metavolcanic Rocks (Kashwakamak Formation and equivalents) (1265 to 1280 Ma)**
4a Felsic tuffs
4b Felsic flows, massive rocks
4f Andesite breccias
4g Mainly flows, basaltic to andesitic composition
4h Feldspar porphyritic mafic dikes
4j Dominantly amphibolite and mafic gneiss, commonly biotite-bearing, likely derived from basaltic to andesitic flows and tuffs
4k Dominantly quartzofeldspathic schist and gneiss, likely derived from intermediate to felsic flows and tuffs

3 **Tholeiitic Mafic Metavolcanic Rocks (Tudor Formation and equivalents) (>1265 Ma)**
Fine-grained, green to dark green weathering amphibolite, garnet amphibolite and mafic gneiss, mainly derived from basaltic flows and tuffs, locally containing pillows, pillow breccias, hyaloclastite, and thin felsic metavolcanic units. Also includes mafic metavolcanic rocks of unknown chemical or stratigraphic affinity

UNKNOWN CONTACT

GRIMSTHORPE DOMAIN (units 1 and 2)

2 **Mafic Intrusive Rocks**
Fine- to medium-grained, dark green to black weathering gabbro, locally foliated

INTRUSIVE CONTACT

CANIFF COMPLEX (>1275 Ma)

1 **Tholeiitic Mafic and Felsic Metavolcanic Rocks**

(trend only, limbs dip in same direction, interpreted)

age in Ma

◆ MA114 Location of modern alluvium sample, sample number preface 03JR- (from Felix, Reid and Easton 2006)

30 Bedding, sedimentary, facing unknown (inclined, vertical)

ABBREVIATIONS

Ag	silver	mag	magnetite
apy	arsenopyrite	mb	marble
Au	gold	mi	mica
ba	barite	Mo	molybdenum
bl	boulangerite	mrl	marl
bm	bismuthinite	mu	muscovite
cal	calcite	po	pyrrhotite
cp	chalcopyrite	Pb	lead
Cu	copper	py	pyrite
di	diopside	qv	quartz vein
dol	dolomite	ra	radioactivity
Fe	iron	scp	scapolite
fel	feldspar	sil	sillimanite
gn	galena	sp	sphalerite
gr	graphite	st	staurolite
grt	garnet	Th	thorium
hb	hornblende	tr	tremolite
hem	hematite	tur	tourmaline
ky	kyanite	U	uranium
		Zn	zinc

bA	biotite Ar/Ar age determination, in Ma
hA	hornblende Ar/Ar age determination, in Ma
mA	muscovite Ar/Ar age determination, in Ma
rU	rutile U/Pb age determination, in Ma
tU	titanite U/Pb age determination, in Ma
zU	zircon U/Pb age determination, in Ma

PROPERTIES AND OCCURRENCES

1 AJM Explorations Limited (U)
2 Boeth Mine (Au, tur, apy)
3 Barrie Syndicate (Zn, Pb, Cu)
4 Big Dipper occurrence (Au, Ag, py, sp)
5 Buckhorn Mines Ltd. (tur, py, gr)
6 Buffadison occurrence (Cu, py)
7 Canadian Arrow Mines Limited (U)
8 Consoliated Imperial Resources Limited (U)
9 Cook (Au, apy)
10 Fyock, M.H. and Associates (U)
11 Ganda Silver Mines Limited (gn, Ag)
12 Gough (Hardie) occurrence (Au, Ag, apy)
13 Helena occurrence (Au, Ag, As, cpy)
14 Keevel Mining Group (U)
15 Kehoe, C. (Au, Cu)
16 Mazinaw base metals (Au, Cu, Zn)
17 Mosque Lake (Victory) Talc (talc)
18 Riddel, D.W. (U)
19 Selco Incorporated (James Mine) (S, cp, qv)
20 Selco Incorporated (Webber Property) (apy, qv)
21 sillimanite occurrence (Little Green Lake) (sil)
22 Star Gold Mine (Au)
23 Summit Lake (Tomclid) (Fe)
25 Wilson, N. (py)

SOURCES OF INFORMATION

Thematic information on this map is tied to a digital base map derived from maps 31C/14, 31C/15, 31F/2 and 31F/3 of the National Topographic System, scale 1:50 000.

Mapping conducted using UTM co-ordinates in North American Datum 1927 (NAD27), Zone 18.

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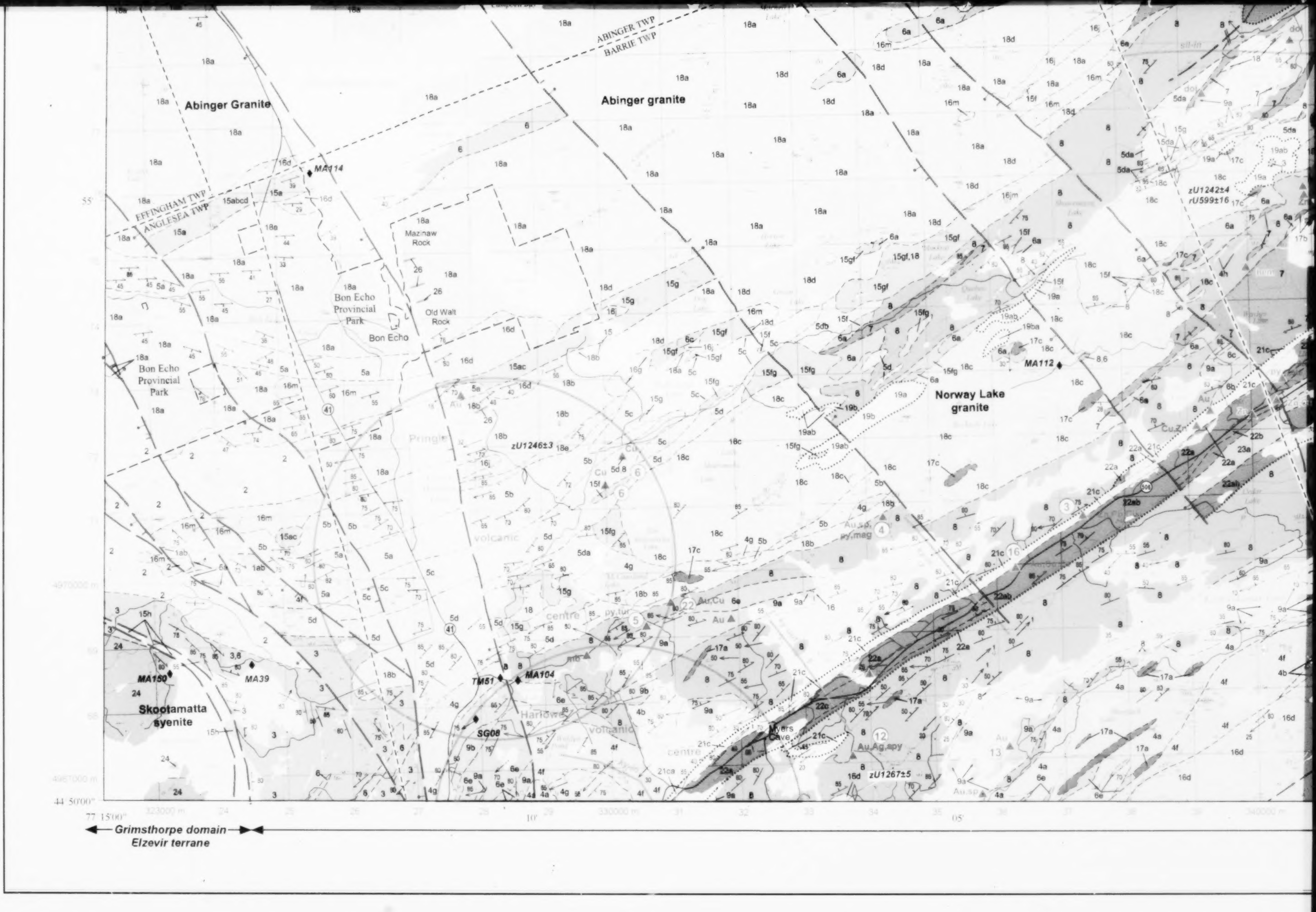
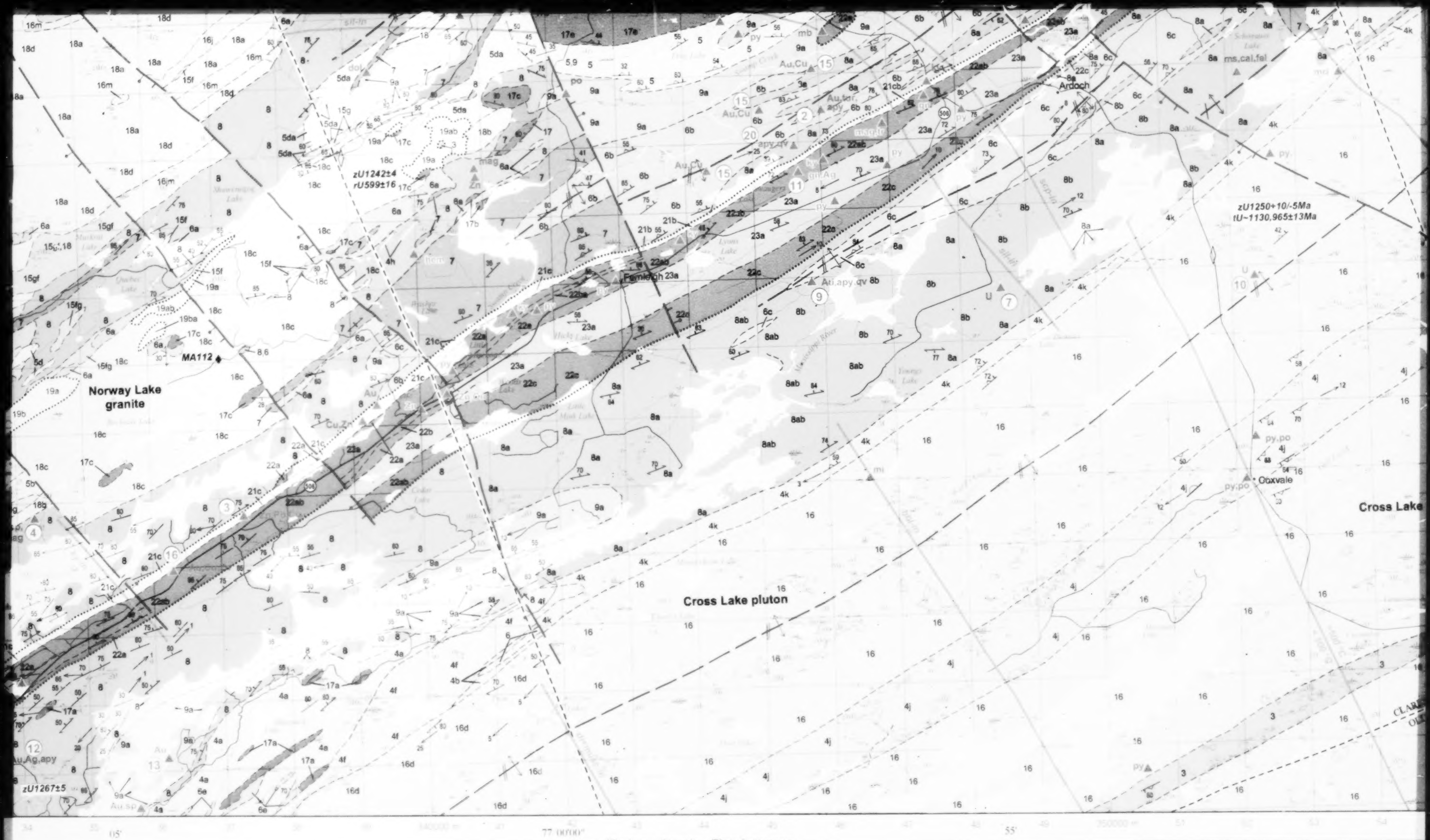
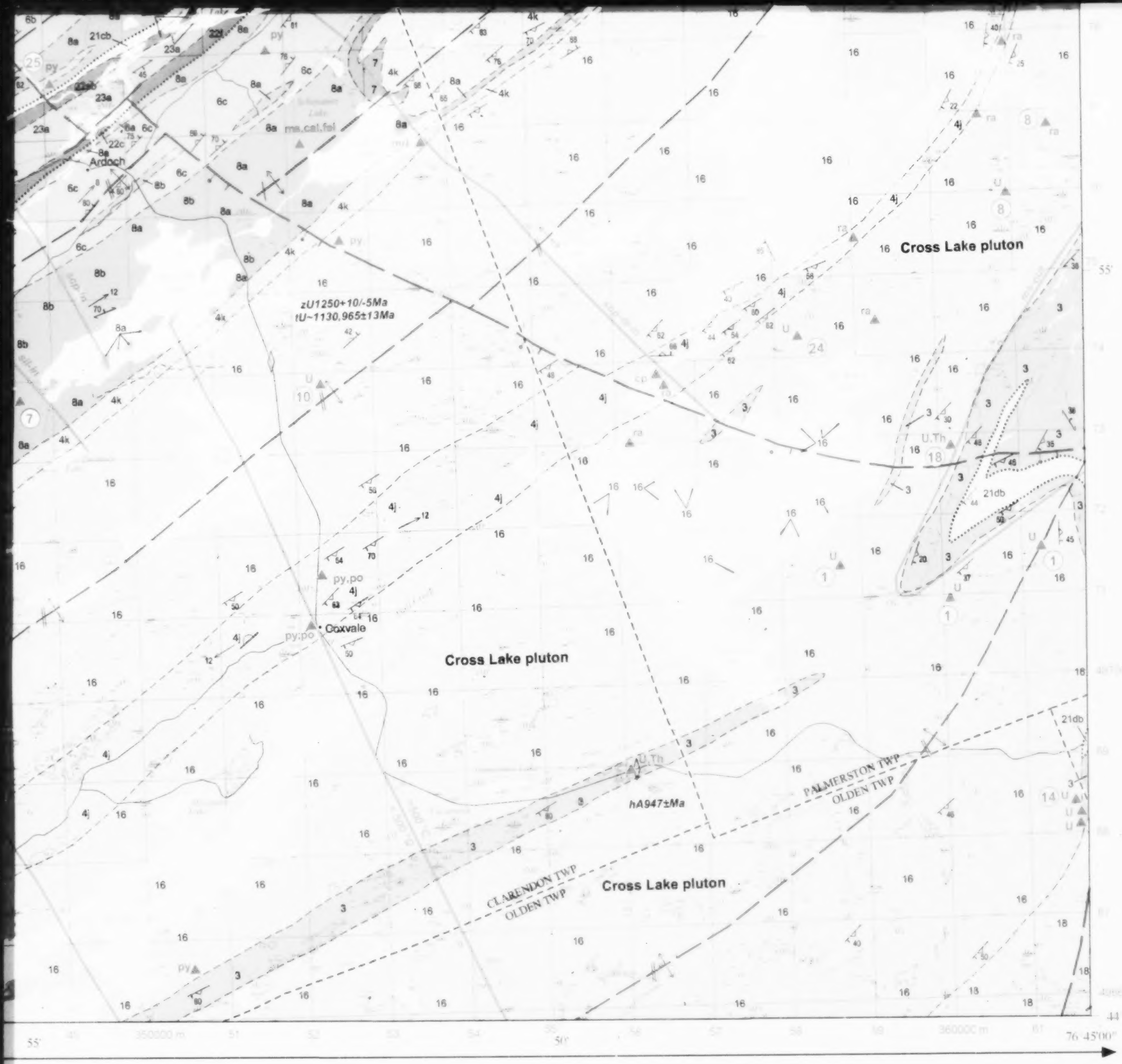

Abinger Granite
Abinger granite
ABINGER TWP
BARRIE TWP
EFFINGHAM TWP
ANGLESEA TWP
MA114
Mazinaw Rock
Old Walt Rock
Bon Echo Provincial Park
Bon Echo
Pringle
volcanic
centre
zU1246±3
Norway Lake granite
MA112
zU1242±4
rU599±16
Au
Cu
Au,Cu
Cu,Zn
Au,sp, py,mag
py,tur
Au,Ag,spy
Au,sp
MA150
MA39
TM51
MA104
SG08
Harlowe
volcanic
centre
Skootamatta syenite
Myers Cave
zU1267±5
55'
44 50'00"
77 15'00"
4970000 m
4967000 m
323000 m
330000 m
340000 m
10'
05'
Grimsthorpe domain
Elzevir terrane


Norway Lake granite
MA112
zU1242±4
rU599±16
Ardoch
Fernleigh
Coxvale
zU1250+10/-5Ma
tU~1130,965±13Ma
Cross Lake
Cross Lake pluton
zU1267±5
Au,Ag,apy
Au,Cu
Au,tur,apy
Au,apy,qv
mag,hm
gn,Ag
Cu,Zn
ms,cal,fel
py,po
05'
77°00'00"
55'
340000 m
350000 m

Mazinaw domain - Elzevir terrane



18e Unit 18b, sheared to mylonitic
18f Medium-grained, gneissic to migmatitic monzogranite, commonly cut by granite pegmatite veins (unit 25)
18j Medium-grained, gneissic granodiorite to quartz diorite
18k Fine- to medium-grained granitoid gneiss
18m Medium-grained, potassium feldspar megacrystic monzogranite, locally grades into augen gneiss

INTRUSIVE CONTACT

Lavant Suite^c (1240 to 1250 Ma)

17

Mafic to Intermediate Intrusive Rocks

17a Fine- to medium-grained gabbro
17b Unit 17a, foliated to gneissic
17c Medium-grained, foliated to gneissic, gabbro, anorthositic gabbro, gabbroic anorthosite
17d Fine- to medium-grained tonalite and granodiorite
17e Medium- to coarse-grained gabbro, foliated to gneissic
17f Grossular-diopside skarn rock
17g Unit 17a, gneissic
17h Unit 17a, foliated to gneissic, locally preserving relict igneous texture
17k Gneissic gabbro and diorite sills and dikes of unknown age and affinity, may include rocks related to units 10 and 17

Elzevir Suite^c (1250 to 1270 Ma)

16

Intermediate Intrusive Rocks

16d Medium-grained tonalite, minor granodiorite
16e Medium-grained granodiorite
16g Intrusion breccia zone to injection migmatite composed of blocks of units 15c, 15b, 15a in unit 16d
16j Unit 16d, foliated to gneissic
16m Intrusion breccia zone to injection migmatite composed of blocks of units 1 and metasedimentary rocks of the Grimsthorpe Group
16n Medium-grained, grey weathering, migmatitic tonalite to granodioritic gneiss, locally cut by granite pegmatite veins (unit 25)

INTRUSIVE CONTACT

Killer Creek Suite^c (>1270 Ma)

15

Mafic Intrusive Rocks

15a Medium-grained gabbro
15b Medium-grained anorthosite, anorthositic gabbro, gabbroic anorthosite
15c Medium- to coarse-grained melanocratic gabbro and hornblendite
15d Fine-grained chlorite-magnetite schist
15f Mafic mylonite derived mainly from unit 15
15g Medium-grained anorthositic gabbro, gabbroic anorthosite, gabbro, foliated to gneissic
15h Mafic mylonite to straight gneiss, derived mainly from units 15, 2, and 3

INTRUSIVE CONTACT

BLACK DONALD DOMAIN (units 10 to 14)

GRENVILLE SUPERGROUP

Metasedimentary Rocks

14

Dolomitic Carbonate Metasedimentary Rocks

14a Dolomite marble, generally medium to coarse grained and massive, may include zones of calc-silicate assemblages (e.g., tremolite, diopside), and minor interlayered siliceous clastic metasedimentary rocks (unit 12)
14b Dolomite marble, medium to coarse grained, white to greenish, containing up to 20% siliceous impurities; local intercalated layers of tremolite-rich dolomitic marble

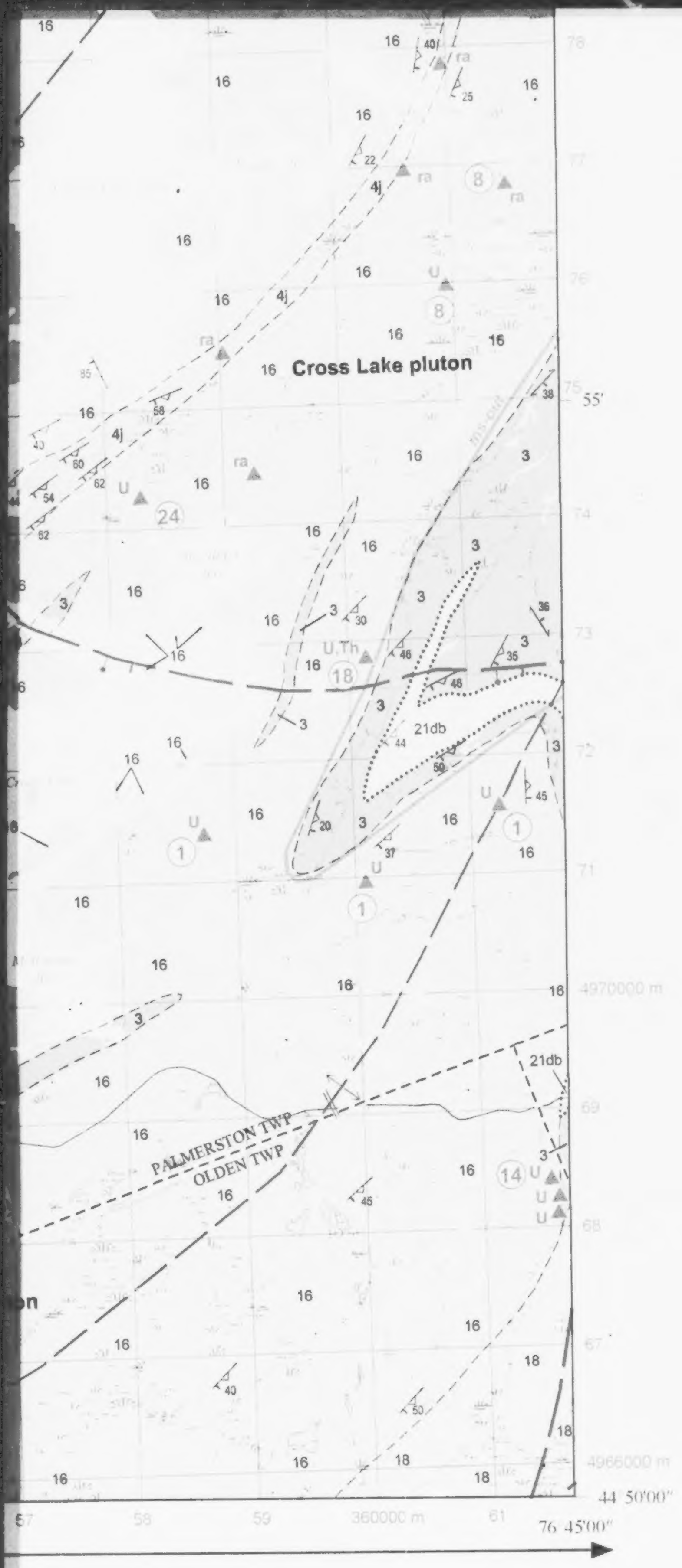
3

2

1

76°15'W
basem
volc
Grim
do

Figure 1.


Cross Lake pluton
PALMERSTON TWP
OLDEN TWP
21db
55'
4970000 m
4966000 m
44 50'00"
76 45'00"
360000 m
57
58
59
61

18e Unit 18b, sheared to mylonitic
18f Medium-grained, gneissic to migmatitic monzogranite, commonly cut by granite pegmatite veins (unit 25)
18j Medium-grained, gneissic granodiorite to quartz diorite
18k Fine- to medium-grained granitoid gneiss
18m Medium-grained, potassium feldspar megacrystic monzogranite, locally grades into augen gneiss

INTRUSIVE CONTACT

Lavant Suite[c] (1240 to 1250 Ma)

17

Mafic to Intermediate Intrusive Rocks
17a Fine- to medium-grained gabbro
17b Unit 17a, foliated to gneissic
17c Medium-grained, foliated to gneissic, gabbro, anorthositic gabbro, gabbroic anorthosite
17d Fine- to medium-grained tonalite and granodiorite
17e Medium- to coarse-grained gabbro, foliated to gneissic
17f Grossular-diopside skarn rock
17g Unit 17a, gneissic
17h Unit 17a, foliated to gneissic, locally preserving relict igneous texture
17k Gneissic gabbro and diorite sills and dikes of unknown age and affinity, may include rocks related to units 10 and 17

Elzevir Suite[c] (1250 to 1270 Ma)

16

Intermediate Intrusive Rocks
16d Medium-grained tonalite, minor granodiorite
16e Medium-grained granodiorite
16g Intrusion breccia zone to injection migmatite composed of blocks of units 15c, 15b, 15a in unit 16d
16j Unit 16d, foliated to gneissic
16m Intrusion breccia zone to injection migmatite composed of blocks of units 1 and metasedimentary rocks of the Grimsthorpe Group
16n Medium-grained, grey weathering, migmatitic tonalite to granodioritic gneiss, locally cut by granite pegmatite veins (unit 25)

INTRUSIVE CONTACT

Killer Creek Suite[c] (>1270 Ma)

15

Mafic Intrusive Rocks
15a Medium-grained gabbro
15b Medium-grained anorthosite, anorthositic gabbro, gabbroic anorthosite
15c Medium- to coarse-grained melanocratic gabbro and hornblendite
15d Fine-grained chlorite-magnetite schist
15f Mafic mylonite derived mainly from unit 15
15g Medium-grained anorthositic gabbro, gabbroic anorthosite, gabbro, foliated to gneissic
15h Mafic mylonite to straight gneiss, derived mainly from units 15, 2, and 3

INTRUSIVE CONTACT

BLACK DONALD DOMAIN (units 10 to 14)

GRENVILLE SUPERGROUP

Metasedimentary Rocks

14

Dolomitic Carbonate Metasedimentary Rocks
14a Dolomite marble, generally medium to coarse grained and massive, may include zones of calc-silicate assemblages (e.g., tremolite, diopside), and minor interlayered siliceous clastic metasedimentary rocks (unit 12)
14b Dolomite marble, medium to coarse grained, white to greenish, containing up to 20% siliceous impurities, local intercalated layers of tremolite-rich dolomitic marble

4j Dominantly amphibolite and mafic gneiss, commonly biotite-bearing, likely derived from basaltic to andesitic flows and tuffs
4k Dominantly quartzofeldspathic schist and gneiss, likely derived from intermediate to felsic flows and tuffs

3

Tholeiitic Mafic Metavolcanic Rocks (Tudor Formation and equivalents) (>1265 Ma)
Fine-grained, green to dark green weathering amphibolite, garnet amphibolite and mafic gneiss, mainly derived from basaltic flows and tuffs, locally containing pillows, pillow breccias, hyaloclastite, and thin felsic metavolcanic units. Also includes mafic metavolcanic rocks of unknown chemical or stratigraphic affinity

UNKNOWN CONTACT

GRIMSTHORPE DOMAIN (units 1 and 2)

2

Mafic Intrusive Rocks
Fine- to medium-grained, dark green to black weathering gabbro, locally foliated

INTRUSIVE CONTACT

CANIFF COMPLEX (>1275 Ma)

1

Tholeiitic Mafic and Felsic Metavolcanic Rocks
1a Amphibolite and mafic schist to gneiss, likely derived from basaltic flows and tuffs
1b Unit 1a, pillowed

6	**Buffadison occurrence (Cu, py)**
7	Canadian Arrow Mines Limited (U)
8	Consoliated Imperial Resources Limited (U)
9	Cook (Au, apy)
10	Fyock, M.H. and Associates (U)
11	Ganda Silver Mines Limited (gn, Ag)
12	Gough (Hardie) occurrence (Au, Ag, apy)
13	Helena occurrence (Au, Ag, As, cpy)
14	Keevel Mining Group (U)
15	Kehoe, C. (Au, Cu)
16	Mazinaw base metals (Au, Cu, Zn)
17	Mosque Lake (Victory) Talc (talc)
18	Riddel, D.W. (U)
19	Selco Incorporated (James Mine) (S, cp, qv)
20	Selco Incorporated (Webber Property) (apy, qv)
21	sillimanite occurrence (Little Green Lake) (sil)
22	Star Gold Mine (Au)
23	Summit Lake (Tomclid) (Fe)
25	Wilson, N. (py)

[a] The Precambrian legend is a tectonostratigraphic one, and stratigraphic order is only in part implied by numerical order.
[b] All Precambrian rocks have been subjected to regional metamorphism; many non-metamorphic terms are used for the sake of brevity and where the protolith is established.
[c] Igneous rock suites and their ages are adapted from Lumbers et al. (1990) and Easton (1992).

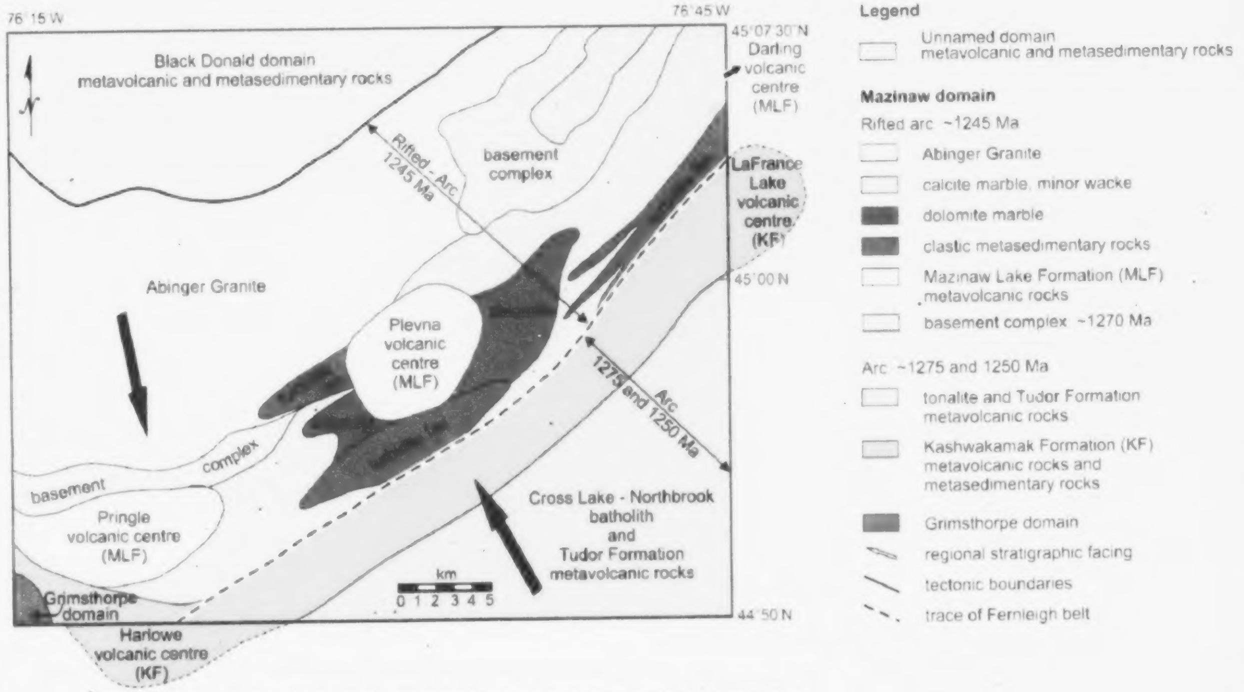

76 15 W
76 45 W
45 07 30 N
45 00 N
44 50 N
Black Donald domain metavolcanic and metasedimentary rocks
Rifted - Arc 1245 Ma
basement complex
Darling volcanic centre (MLF)
LaFrance Lake volcanic centre (KF)
Abinger Granite
Plevna volcanic centre (MLF)
1275 and 1250 Ma Arc
basement complex
Pringle volcanic centre (MLF)
Cross Lake - Northbrook batholith and Tudor Formation metavolcanic rocks
km
0 1 2 3 4 5
Grimsthorpe domain
Harlowe volcanic centre (KF)
Legend
Unnamed domain metavolcanic and metasedimentary rocks
Mazinaw domain
Rifted arc ~1245 Ma
Abinger Granite
calcite marble, minor wacke
dolomite marble
clastic metasedimentary rocks
Mazinaw Lake Formation (MLF) metavolcanic rocks
basement complex ~1270 Ma
Arc ~1275 and 1250 Ma
tonalite and Tudor Formation metavolcanic rocks
Kashwakamak Formation (KF) metavolcanic rocks and metasedimentary rocks
Grimsthorpe domain
regional stratigraphic facing
tectonic boundaries
trace of Fernleigh belt

Figure 1. Interpretative sketch showing the main tectonic elements present on the map face

18e Unit 18b, sheared to mylonitic
18f Medium-grained, gneissic to migmatitic monzogranite commonly cut by granite pegmatite veins (unit 25)
18j Medium-grained, gneissic granodiorite to quartz diorite
18k Fine- to medium-grained granitoid gneiss
18m Medium-grained, potassium feldspar megacrystic monzogranite, locally grades into augen gneiss

INTRUSIVE CONTACT

Lavant Suite[c] (1240 to 1250 Ma)

7 **Mafic to Intermediate Intrusive Rocks**
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Elzevir Suite[c] (1250 to 1270 Ma)

16 **Intermediate Intrusive Rocks**
16d Medium-grained tonalite, minor granodiorite
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16n Medium-grained, grey weathering, migmatitic tonalite to granodioritic gneiss, locally cut by granite pegmatite veins (unit 25)

INTRUSIVE CONTACT

Killer Creek Suite[c] (>1270 Ma)

15 **Mafic Intrusive Rocks**
15a Medium-grained gabbro
15b Medium-grained anorthosite, anorthositic gabbro, gabbroic anorthosite
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INTRUSIVE CONTACT

BLACK DONALD DOMAIN (units 10 to 14)

GRENVILLE SUPERGROUP

tasedimentary Rocks

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UNKNOWN CONTACT

GRIMSTHORPE DOMAIN (units 1 and 2)

2 **Mafic Intrusive Rocks**
Fine- to medium-grained, dark green to black weathering gabbro, locally foliated

INTRUSIVE CONTACT

CANIFF COMPLEX (>1275 Ma)

1 **Tholeiitic Mafic and Felsic Metavolcanic Rocks**
1a Amphibolite and mafic schist to gneiss, likely derived from basaltic flows and tuffs
1b Unit 1a, pillowed

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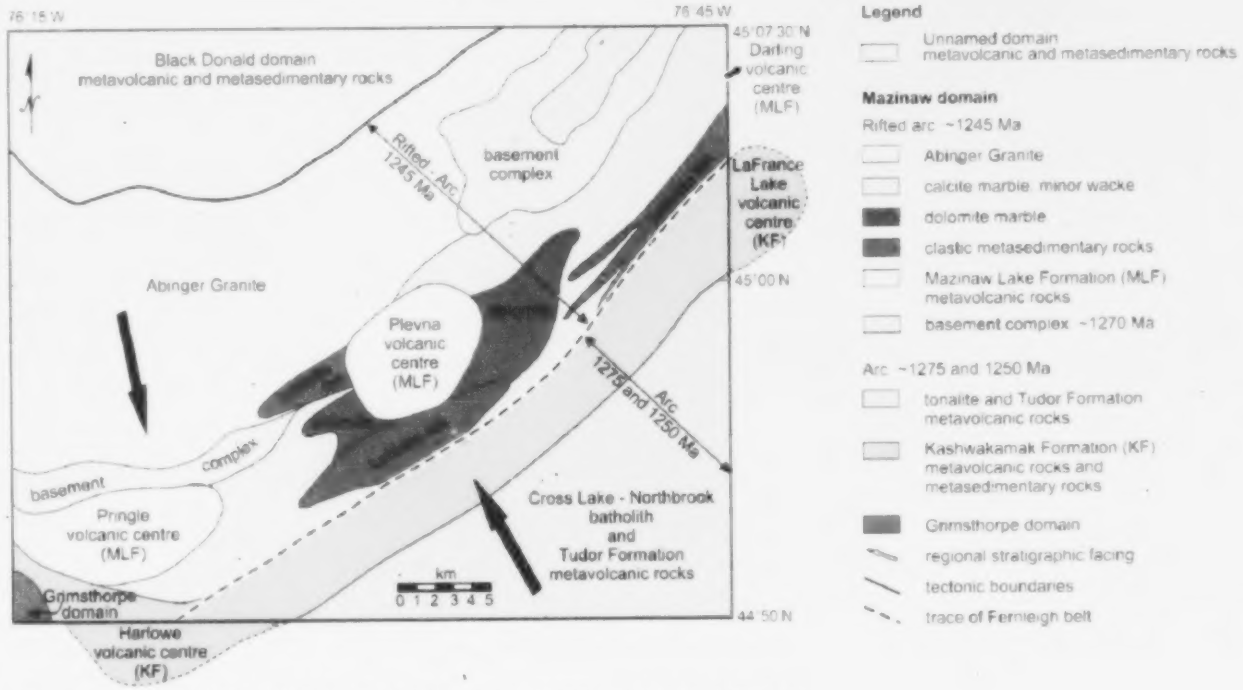
16 Mazinaw base metals (Au, Cu, Zn)
17 Mosque Lake (Victory) Talc (talc)
18 Riddel, D.W. (U)
19 Selco Incorporated (James Mine) (S, cp, qv)
20 Selco Incorporated (Webber Property) (apy, qv)
21 sillimanite occurrence (Little Green Lake) (sil)
22 Star Gold Mine (Au)
23 Summit Lake (Tomclid) (Fe)
25 Wilson, N. (py)


76°15'W
76°45'W
45°07'30"N
45°00'N
44°50'N
N
Black Donald domain
metavolcanic and metasedimentary rocks
Darling volcanic centre (MLF)
Rifted - Arc 1245 Ma
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LaFrance Lake volcanic centre (KF)
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basement complex
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Rifted arc ~1245 Ma
Abinger Granite
calcite marble, minor wacke
dolomite marble
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Arc ~1275 and 1250 Ma
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Grimsthorpe domain
regional stratigraphic facing
tectonic boundaries
trace of Ferneigh belt

Figure 1. Interpretative sketch showing the main tectonic elements present on the map face

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Magnetic declination approximately 12°01'W in 2006 at centre of map area.

Geology is not tied to survey lines.

Metric conversion factor: 1 foot = 0.3048 m

CREDITS

Geological compilation by R.M. Easton, 1992, 2001–2002, 2006.

Digital drafting by S. Josey, R.M. Easton and E.I. Murphy.

Cartographic production by A. Evers.

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Issued 2006.

Information from this publication may be quoted if credit is given. It is recommended that reference to this map be made in the following form:

Easton, R.M. 2006. Precambrian geology, Cloyne–Plevna–Ompah area; Ontario Geological Survey, Preliminary Map P.3443, scale 1:50 000.

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